TM-70-2034-8

TECHNICAL MEMORANDUM

DESCRIPTION OF THE COMMUNICATIONS SYSTEMS OF THE SPACE VEHICLE FOR SKYLAB MISSIONS SL-1 THROUGH SL-4

Bellcomm

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AUTHOR(S)- A. G. Weygand

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ABSTRACT

The communications systems of the Skylab modules used in Missions SL-1 through SL-4 are described including the crewmen, the Saturn IB and Saturn V Launch Vehicles, the Command and Service Module, the Saturn V Workshop and the Apollo Telescope Mount. The interfaces between the communications of these Skylab Program elements are described for all of the different nominal space vehicle module configurations which will be used. These descriptions reflect the designs of the communications systems that were current as of June, 1970.

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TABLE OF CONTENTS

Table of Contents

Table of Contents

Table of Contents

Table of Contents

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TECHNICAL MEMORANDUM

1.0 INTRODUCTION

The communications systems of the space vehicle modules to be used in missions SL-1 through SL-4 of the Skylab Program and the interfaces between the communications systems of these space vehicle modules are described in this memorandum. An attempt has been made by the writer to consolidate and present in a single document for convenient reference information on the communications systems of the Skylab Program space vehicle modules gathered during various meetings and reviews or available in existing diverse documentation. To the best of the writer's knowledge, the descriptive information contained in this memorandum reflects the design of the communications systems of the various modules that was current as of June, 1970. The reader should remain aware that the design of some of the systems described in this memorandum such as the teleprinter, television system, and the data system of the Earth Resources Experiments Package (EREP) is still fluid at this time and could change.

The communications systems and the interfaces between the communications systems of the various Skylab Program space vehicle modules are discussed in terms of all of the different nominal space vehicle module configurations which will occur during the Skylab Program missions of interest, SL-1 through SL-4, inclusive. These configurations are defined with respect to the space vehicle modules involved in Section 1.1 and with respect to the overall Skylab Program mission plan in Section 1.2. A brief description of the communications systems of the various space vehicle modules is presented in Section 1.3 for those readers who desire only a broad overview. A more detailed description of the voice communications, instrumentation and telemetry, up-data, tracking, television, and antenna systems is presented in Section 2.0 for each module in each configuration and for all communications systems interfaces between modules of each configuration. It should be noted that the caution and warning systems of the various modules are not described in this memorandum.

1.1 Space Vehicle Modules

The space vehicle modules used in missions SL-1 through SL-4 are summarized below for each mission configuration discussed in this memorandum.

(a) The mission SL-1 space vehicle (Figure 1.1) consists of a Saturn V Launch Vehicle, an Airlock Module (AM), a Multiple Docking Adapter (MDA), an Apollo Telescope Mount (ATM), and a Payload Shroud (PS). The S-IVB stage of the Saturn V Launch Vehicle will be modified to permit the liquid hydrogen tank to be utilized as an Orbital Workshop (OWS) by the crew in shirtsleeve attire. The S-IVB stage will be launched without fuel in the liquid hydrogen and liquid oxygen tanks. The combination of the MDA, AM, and OWS (plus the Instrument Unit (IU) of the Saturn V Launch Vehicle and part of the PS) is defined as the Saturn Workshop (SWS). Although the ATM is technically part of the SWS, it will be treated separately in this memorandum.

(b) The mission SL-2 space vehicle consists of a Saturn IB Launch Vehicle, a Block II Apollo Spacecraft Lunar Module Adapter (SLA), a modified Block II Command and Service Module (CSM), and a Launch Escape System (LES).

(c) The mission SL-1/SL-2 space vehicle consists of the SWS and ATM from mission SL-1 and the CSM from mission SL-2. The SWS, the ATM, and a docked CSM shown in Figure 1.2 is defined as the Orbital Assembly (OA).

(d) The mission SL-3 space vehicle consists of a Saturn IB Launch Vehicle, a SLA, a CSM, and a LES.

(e) The mission SL-1/SL-3 space vehicle consists of the SWS and ATM from mission SL-1 and the CSM from mission SL-3.

(f) The mission SL-4 space vehicle consists of a Saturn IB Launch Vehicle, a SLA, a CSM, and a LES.

(g) The mission SL-1/SL-4 space vehicle consists of the SWS and ATM from mission SL-1 and the CSM from mission SL-4.

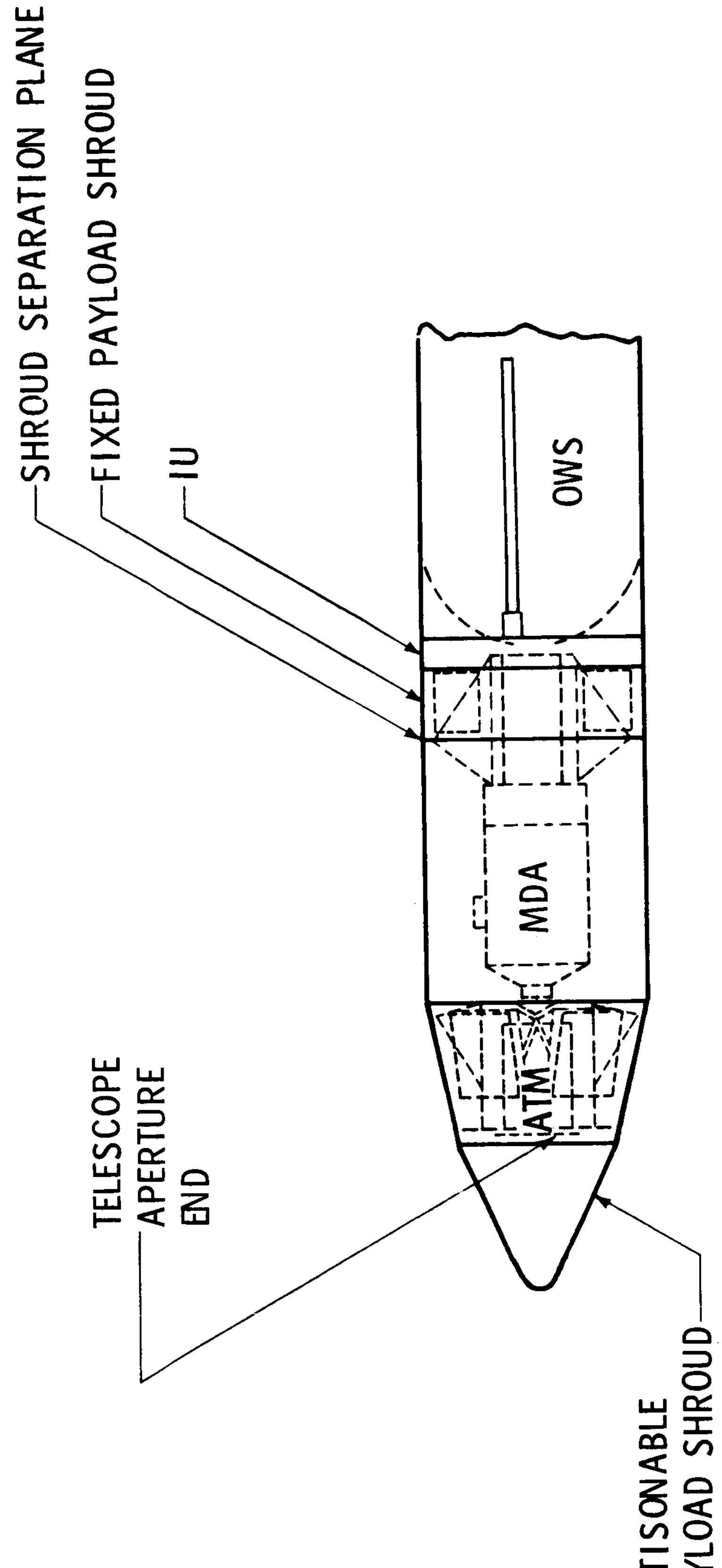

FIGURE I.I - SATURN WORKSHOP LAUNCH CONFIGURATION

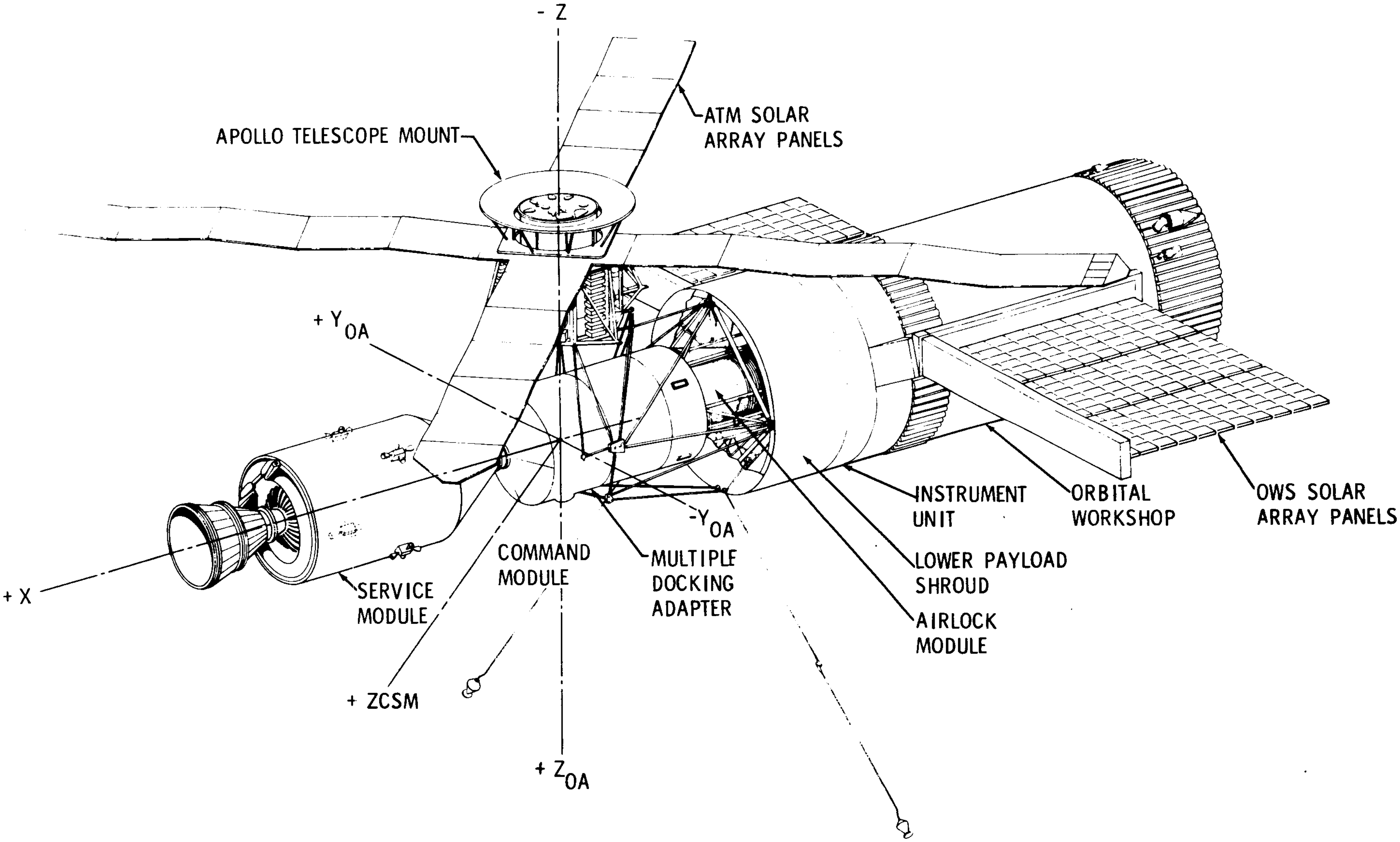

FIGURE I.2 - ORBITAL ASSEMBLY

1.2 Mission Description

1.2.1 Mission SL-1

Mission SL-1 will be unmanned and will be launched in a northerly direction from Launch Complex 39 (pad 39A) at Cape Kennedy into an approximately circular Earth orbit of 235 nautical miles altitude at approximately 50 degrees inclination. The ATM as shown in (Figure 1.1) will be launched in a position above the forward end of the MDA. Separation of the S-II stage from the SWS will be accomplished in Earth orbit via firing of the S-II stage retrorockets immediately after completion of S-II stage engine shutdown thrust decay. Immediately after separation of the S-II stage, the SWS under IU control will begin a pitch maneuver in the nose down direction and the upper portion of the AM will be jettisoned. Jettisoning of the S-II stage and the upper portion of the PS will be accomplished in a manner which will preclude recontact with the SWS for a minimum period of eight months, the nominal useful lifetime of the SWS. Then the VHF discone antennas of the AM will be deployed. The ATM will then be positioned so that the apertures of the telescopes of the solar experiments point in the direction of the minus Z-axis of the body coordinate system of the SWS. Then the solar arrays of both the ATM and the OWS and the meteroid shields will be deployed. The SWS will be repositioned through use of the Thruster Attitude Control Subsystem (TACS) of the OWS and then inertially stabilized through use of Control Moment Gyros (CMG's) of the ATM with its longitudinal axis (X-axis) lying in the orbital plane and its minus Z-axis pointed towards the Sun. With the minus Z-axis pointing at the Sun at orbital noon, the plus Z-axis of the SWS will be in the direction of the velocity vector. Immediately prior to each rendezvous of the CSM with the SWS, the TACS will be used to change and then stabilize the attitude of the SWS so that the Z-axis of the SWS is coincident with the local vertical (Z-LV), the plus Z-axis is pointing to the Earth, and the X-axis is in the orbital plane (X-IOP). The Z-LV/X-IOP attitude will be maintained for approximately two orbits until the CSM rendezvous and docking maneuver has been completed.

1.2.2 Mission SL-2

Mission SL-2 will be manned and will be launched in a northerly direction from Launch Complex 39 (pad 39B) at Cape Kennedy approximately one day after the launch of SL-1. The manned CSM will separate from the launch vehicle immediately after insertion into an elliptical Earth orbit approximately 81 by 120 nautical miles in altitude. The exact time of launch and the exact inclination of the elliptical orbit will be chosen prior to launch of mission SL-2 to facilitate rendezvous of the CSM with the SWS of mission SL-1. At the appropriate time, the SM propulsion and attitude control system will be used to rendezvous the CSM with the orbiting SWS.

1.2.3 Mission SL-1/SL-2

The CSM of mission SL-2 will dock to the axial port of the MDA of the SWS of mission SL-1 as shown in (Figure 1.2). After the docking maneuver has been completed, the attitude of the OA will be changed to and stabilized in a solar inertial reference attitude. The OA will remain inertially stabilized during mission SL-1/SL-2 with its X-axis lying in the orbital plane and its minus Z-axis pointing toward the Sun except during those periods when the Earth resources experiments are being conducted which require the OA to be stabilized in the Z-LV/X-IOP attitude.

After the docking maneuver has been completed, the CM hatch will be opened and a crewman prepared for intravehicular activity (IVA) will connect the electrical umbilicals between the CSM and MDA and will otherwise activate the SWS systems as required to provide a shirtsleeve environment throughout the OA. The mission will be open-ended with a planned duration for the crew of 28 days during which time medical, habitability, astronaut mobility and work capability, solar astronomy, Earth resources and other experiments will be conducted. The CSM will be normally unmanned and will operate in a quiescent mode although periodic operation/monitoring of the CSM systems will be required to ensure a satisfactory deorbit capability. Extravehicular activity (EVA) may be performed by up to two crewmen through the airlock hatch of the AM. After completion of the activities of mission SL-1/SL-2, the SWS systems will be placed in a storage mode, the CM will return to the Earth with the crew, and the SWS will remain inertially stabilized with its X-axis lying in the orbital plane and its minus Z-axis pointing toward the Sun.

1.2.4 Mission SL-3

Like mission SL-2, mission SL-3 will be manned and will be launched in a northerly direction from launch pad 39B at Cape Kennedy and the CSM will rendezvous with the SWS of mission SL-1. This launch will occur approximately three months after the launch date of mission SL-2 as dictated by launch and recovery lighting considerations.

1.2.5 Mission SL-1/SL-3

Mission SL-1/SL-3 will be essentially a repeat of mission SL-1/SL-2 except for the mix of the experiments conducted and for the planned mission duration. Mission SL-1/SL-3 will be open-ended with a planned duration for the crew of 56 days.

1.2.6 Mission SL-4

Like missions SL-2 and SL-3, mission SL-4 will be manned and will be launched in a northerly direction from launch pad 39B at Cape Kennedy and the CSM will rendezvous with the SWS of mission SL-1. Launch of mission SL-4 will occur approximately three months after the launch date of mission SL-3 dictated by launch and recovery lightning considerations.

1.2.7 Mission SL-1/SL-4

Mission SL-1/SL-4 will be essentially the same as mission SL-1/SL-3 except for the mix of the experiments conducted. Mission SL-1/SL-4 will complete the planned use of the SWS. Mission SL-1/SL-4 will be open-ended with a planned duration for the crew of 56 days.

1.3 <u>Summary Description of Space Vehicle Module Communications Systems</u>

The various space vehicle modules which will be used during at least a portion of the Skylab Program missions SL-1 through SL-4 will include: (a) the Saturn V Launch Vehicle, (b) the SWS, (c) the ATM, (d) the Saturn IB Launch Vehicle, (e) the CSM, and (f) the crewmen. The communications systems of these modules as understood by the writer are briefly described in the following paragraphs. The radio frequency (RF) communications links of these modules are listed in Table 1.3.1.

1.3.1 Communications System of the Saturn V Launch Vehicle

The S-IC and S-II stages and IU of the Saturn V Launch Vehicle used in mission SL-1 will be equipped with the Same VHF telemetry systems, UHF command-destruct systems, C-band radar transponder system, and Command and Communications System (CCS) as the operational Saturn V Launch Vehicles to be used in the Apollo Program. As in the Apollo Program, the battery power supplies of the S-IVD/IU will be exhausted at approximately 7.5 hours after lift-off and the battery supply associated with the CCS transponder will be exhausted at approximately 72 hours after lift-off. Since the S-II stage will be inserted into Earth orbit, the command-destruct system of the S-II stage will be modified to accept and execute a command to deactivate or "safe" the stage command-destruct system.

The S-IVB stage associated with this launch vehicle will be modified to serve as the OWS and the communications system normally associated with an S-IVB stage of a Saturn V Launch

TABLE 1.3.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLES USED FOR THE SKYLAB PROGRAM MISSIONS

Location	System	Frequency (MHz) Transmit	Frequency (MHz) Receive	Modulation
S-IC	Telemetry	256.2		FM/FM
	Telemetry	244.3		PCM/FM
	Command-Destruct		450	FSK/FM
S-II	Telemetry	240.2		FM/FM
	Telemetry	232.9		FM/FM
	Telemetry	248.6		PCM/FM
	Command-Destruct		450	FSK/FM
IU (Sat. V)	Telemetry	250.7		FM/FM
	Telemetry	245.3		PCM/FM
	CCS	2282.5	2101.8	PM
	C-Band Transponder	5765.0	5690.0	Pulse
S-IB (Sat.IB)	Telemetry	240.2		FM/FM
	Telemetry	256.2		PCM/FM
	Command-Destruct		450	FSK/FM
S-IVB	Telemetry	258.5		PCM/FM
	Command-Destruct		450	FSK/FM
IU (Sat. V)	Telemetry	250.7		FM/FM
	Telemetry	245.3		PCM/FM
	Up-Data		450	FSK/FM
	C-Band Transponder	5765.0	5690.0	Pulse
SWS	Telemetry, Recorded Voice	230.4		PCM/FM, FM
	Telemetry, Recorded Voice	235.0		PCM/FM, FM
	Telemetry, Recorded Voice	246.3		PCM/FM, FM
	Up-Data		450	PSK/FM
	VHF Ranging	296.8	259.7	AM
	Experiment M509/T020 Telemetry*	26.0	26.0	FSK

*Internal to the OWS

TABLE 1.3.1 (Continued)

Location	System	Frequency (MHz) Transmit	Frequency (MHz) Receive	Modulation
ATM	Telemetry	231.9		PCM/FM
	Telemetry	237.0		PCM/FM
	Up-Data		450	PSK/FM
CSM	USB Transponder	2287.5	2106.4	PM
	FM Transmitter	2272.5		FM
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM
	Recovery Beacon	243.0		ICW

Vehicle will be removed. The communications system added to this S-IVB stage as part of its transformation into the OWS is briefly described in the following section.

1.3.2 Communications System of the Saturn V Workshop

The communications system of the SWS will be comprised of:

(a) An audio distribution hardline network including redundant and independent voice communications hardlines, an audio load compensator in each hardline, and communications panels located throughout the SWS.

(b) An instrumentation and telemetry system including a measuring subsystem, redundant pulse code modulation (PCM) programmers, a PCM interface box (IB), three autonomous data systems, three tape recorders, and four VHF FM telemetry transmitters.

(c) An up-data system including redundant UHF up-data receivers and decoder units, an up-data receiver and decoder unit redundancy control subsystem, a command relay driver unit (CRDU), an interface electronics unit (IEU), and a teleprinter.

(d) A television system including a video distribution network.

(e) A VHF ranging transponder system including a range tone transfer assembly (RTTA), one VHF AM receiver, one VHF AM transmitter, and a VHF antenna.

(f) A VHF/UHF antenna system including a launch antenna subsystem and an Earth orbit antenna subsystem.

The audio distribution hardline network in conjunction with two audio centers of the CM will provide voice communications conference capability to crewmen located anywhere in the OA or when performing extravehicular activity (EVA). Communications panels located for convenience in the various work and habitability areas of the SWS will provide the interface between the personal communications system (PCS) of each crewman and the voice communications hardlines. The communications panels in selected locations will be provided with a fixed speaker and microphone to provide a crewman with a simplex voice communications capability without the use of his PCS. Each communications panel will be provided with the necessary controls and displays required by a crewman for remote control of the modes of operation of the audio distribution hardline network. The audio load compensator in each of the two independent voice communications hardlines will provide the interface between that hardline and a different audio center of the CM and will provide an audio signal suitable for on-board storage by the tape recordings of the instrumentation and telemetry system of the SWS.

The redundant PCM telemetry programmers which will be of the type used in the spacecraft of the Gemini Program will each have the same fixed program format which will process and combine analog and digital data received from the measuring subsystem of the SWS into a 51.2 kilobits per second (kbps) PCM data stream for transmission to the Manned Space Flight Network (MSFN) in real-time. In addition, the PCM programmer in operation will provide for on-board storage and subsequent transmission to the MSFN in delayed-time a 5.12 kbps PCM data stream which will be a subset of the 51.2 kbps PCM data stream. The PCM IB will be provided to enable either PCM programmers to accommodate a greater number of multiplexers in the measuring subsystem than it could normally and to create for on-board storage two additional 5.12 kbps PCM data streams which will be different and non-overlapping subsets of the 51.2 kbps PCM data stream.

Separate autonomous data systems will be provided for (a) experiments M509 (Astronaut Maneuvering Unit) and T020 (Foot-Controlled Maneuvering Unit), (b) experiment T013 (Crew-Vehicle Disturbance), and (c) the Earth Resources Experiment Package (EREP). The autonomous data system shared by experiments M509 and T020 and a similar system for experiment T013 will each process and combine the required data from the appropriate experiment into a 5.76 kbps PCM data stream intended for on-board storage and subsequent dump by a tape recorder of the instrumentation and telemetry system of the SWS. The data system supporting experiments M509 and T020 will include an HF FSK telemetry link for use within the OWS for transfer of data, gathered by a measuring subsystem carried by an untethered crewman during the conduct of the experiments, to a fixed receiver and data interleaver for integration with other data to form the 5.76 kbps PCM data stream output from the experiments.

The three tape recorders which will be of the variety used in the Gemini Program will each have two tracks, one to be used for the storage of digital data and the second to be used for the storage of voice information. The recorders will be capable of simultaneous or individual operation. Any one of the five PCM data streams generated for on-board storage, the three 5.12 kbps and two 5.76 kbps PCM data streams discussed above, may be routed to any one of the three tape recorders. Voice information when stored will be recorded on the second track of at least one of the recorders and of any of the other recorders that happen to be operating at that time in the record mode. Each recorder will provide approximately four hours of continuous recording time and will dump the recorded information on both tracks simultaneously in reverse at a tape speed 22 times greater than the record speed. The output of the playback electronics of either track of any one of the three recorders may be routed to any one of the VHF FM transmitters of the instrumentation and telemetry system of the SWS.

Of the four VHF FM transmitters, three will have RF output powers of at least 10 watts and one will have an RF output power of two watts. The two-watt transmitter and one of the 10-watt transmitters will both use the same carrier operating frequency. The two-watt transmitter will be used during the launch phase to transmit the real-time 51.2 kbps PCM data stream generated by the PCM programmer while the 10-watt transmitters will remain inactive to avoid possible damage due to high voltage breakdown when operated in the critical ambient pressures encountered during the launch phase. At some time during Earth orbital coast, the two-watt transmitter will be switched out of operation and the corresponding 10-watt transmitter will be switched in to replace the two-watt transmitter. During Earth orbital coast, signals from any one of seven possible sources, the playback electronics of either track of any one of three recorders and the real-time 51.2 kbps PCM bit stream from the PCM programmer, may be routed to any one of the 10-watt VHF transmitters for transfer to the MSFN.

The redundant UHF up-data receiver and decoder units will be of the variety used in the spacecraft of the Gemini Program and will be capable of detecting and decoding a 450 MHz PSK/FM signal and of routing the decoded commands to the proper location for action. The redundant decoders have the capability of handling and routing up to 32 set/reset commands and in conjunction with the CRDU, which will translate stored program commands into set/reset commands, of handling and routing an additional 198 set/reset commands. To protect against the possible scrub of subsequent revisit Skylab Program missions due to failure of the UHF up-data receiver and decoder unit in operation during the storage period of the SWS since only one of the two units will normally be active, an up-data receiver and decoder unit redundancy control subsystem which will include redundant electronic timers will be provided. When this subsystem is in operation, one of the electronic timers will activate the second unit unless the time-to-go-to-retro (T_r) input to the timer is periodically reset by the MSFN via timing up-data commands through the first unit. If the second unit has been activated, the first unit will be deactivated by command from the MSFN via the second. The electronic timer will reset and will activate the first unit again unless the T_r input to the timer is periodically reset by the MSFN.

An IEU will be included to provide the interface between the signals available at the various applicable test points of the up-data receiver and decoder units and a teleprinter which will produce hard copy printout using a dot-row printing techniques. There will be 150 dots per row which will allow 30 characters to be printed per line composed of seven rows. The IEU will be used to identify up-data messages from the MSFN intended for the teleprinter, to determine the specific alphanumeric symbols whose code was transmitted by the MSFN, and to generate dot-row printing information using a 7x5 matrix for the teleprinter. Each alphanumeric symbol including a "space" will be represented by a unique six-bit code word.

The video distribution network of the SWS will provide the means for routing selected video signals from either the television system of the ATM or from a portable television camera operating from any one of several locations throughout the SWS to the CSM for subsequent transmission to the MSFN via the S-band FM transmitter. A video coax switch will be provided in the MDA which will enable the selection of the video signal to be routed to the CSM/MDA hardwire interface.

The VHF ranging transponder system will enable the CSM to determine the range between the CSM and the SWS during rendezvous. The RTTA, the VHF AM receiver, and the VHF AM transmitter will be of the variety used in the Lunar Module of the Apollo Program. The antenna subsystem of the VHF ranging transponder system of the SWS will be a new design. Ranging signals transmitted by the CSM will be received by the VHF AM receiver, will be turned around by the RTTA, and will be retransmitted by the VHF AM transmitter.

The VHF/UHF antenna system of the SWS will be shared by the VHF FM transmitters of the instrumentation and telemetry system and by the UHF receivers of the up-data system. The launch antenna subsystem will consist of two stub antennas located approximately 90 degrees apart on the stationary portion of the PS. One of the two UHF receivers in each up-data receiver and decoder unit will be hardwired to one of these two antennas.

The second receiver of each up-data receiver and decoder unit and the VHF FM transmitters will be multiplexed and routed through a coax switch to the second stub antenna. The Earth orbit antenna subsystem will consist of two discone antennas, each deployed on a different non-retractable boom forty feet in length and spaced approximately 90 degrees apart, and the stub antenna of the launch antenna used exclusively by the UHF up-data receivers. The multiplexed VHF FM transmitters and the UHF up-data receivers discussed above may be switched from the launch antenna subsystem to either one of the two discone antennas of the Earth orbit antenna subsystem.

1.3.3 Communications System of the Apollo Telescope Mount

The communications system of the ATM will be comprised of:

(a) An instrumentation and telemetry system including a measuring subsystem, redundant pulse code modulation/digital data acquisition system (PCM/DDAS) assemblies, the Auxiliary Storage and Playback (ASAP) assembly, two VHF FM telemetry transmitters and a VHF antenna subsystem.

(b) An up-data system including two UHF receiver and decoder combinations and a UHF antenna subsystem.

(c) A television system including five television cameras, two television display monitors, redundant sync generators, and two video coax switches with sync adder circuitry included in each switch.

The redundant PCM/DDAS assemblies which will be of the variety used in the Saturn Launch Vehicles in the Apollo Program will each have the same fixed program format which will process and combine analog and digital data received from the measuring subsystem of the ATM into a 72 kbps PCM data stream intended for transmission to the MSFN in real-time. In addition to this serial PCM data stream output, the PCM/DDAS assemblies will also provide a 10-bit parallel word output which contains the same information as the serial 72 kbps PCM data stream. The 10-bit parallel work output from the operating PCM/DDAS assembly will be routed to the ASAP assembly where a total of 400 preselected 10-bit words will be extracted each second from the 7200 words available. The same 400 words will be extracted each second. The extracted digital data will be converted into a serial PCM data stream of 4 kbps suitable for on-board storage. Redundant tape recorders will be included in the ASAP assembly, each of which will be capable of recording PCM data at a rate of 4 kbps for a maximum continuous duration of approximately 90 minutes and will be capable of dumping the stored information at a rate 18 times faster than the record rate. It will be possible to operate the redundant tape recorder once per day without significantly degrading the reliability of the ASAP on a sequential basis with the primary tape recorder to provide continuous record times of up to 180 minutes. Since the recorders will be pseudo-endless loop recorders, rewinding of the tape prior to playback will not be required and the data recorded first will be dumped first at a rate of 72 kbps. However, regardless of the amount of data stored, it will always take five minutes of recorder playback time for the data which was recorded last to be dumped. If data has been stored on both recorders, data can be dumped from only one recorder at a time.

It will be possible to route the real-time 72 kbps PCM signal output from one of the redundant PCM/DDAS assemblies or the delayed time 72 kbps PCM signal output from one of the redundant tape recorders of the ASAP to either or both of the two VHF FM telemetry transmitters. The VHF antenna subsystem will include two antenna elements -- one will be located near the end of solar panel wing I and the second will be located near the end of solar panel wing IV. The combined outputs from the two VHF FM telemetry transmitters may be routed to either one of these two antenna elements for radiation to the MSFN.

The two UHF receiver and decoder combinations will be of the variety used in the Saturn Launch Vehicles in the Apollo Program. Both UHF receiver and decoder combinations will be active continuously. One UHF receiver and decoder combination will be connected to a UHF antenna element mounted near the end of solar panel wing I and the second UHF receiver and decoder combination will be connected to a UHF antenna element mounted near the end of solar panel wing III. The UHF receiver and decoder combinations will be capable of detecting and decoding a 450 MHz PSK/FM signal and of routing the decoded commands to the appropriate switch selector or ATM digital computer for action. The decoders will determine whether or not the received up-data message was a valid ATM command (address, format, and sub-bit encoding) and will provide a signal to the instrumentation and telemetry system of the ATM for transfer to the MSFN indicating receipt of a valid command.

The closed circuit portion of the ATM television system, which will include five television cameras in the ATM and two television display monitors located on the ATM control and display panel in the MDA, will enable a crewman in the MDA to monitor the field of view of the optics used for the various ATM solar experiments. Two video coax switches, each switch associated with a different one of the two monitors, will be provided to enable a crewman to select the output of any one of the five television cameras for display on either of the two monitors. Redundant sync generators will be included to provide the horizontal and vertical drive signals to each television camera and to each monitor for synchronization. These five television cameras will provide standard commercial Electronic Industries Association (EIA) format video signal outputs with the exception of the sync pulses which are absent.

These two video coax switches will also be used to select the output of which camera(s) will be available for transmission to the MSFN via the S-band FM transmitter of the CSM. Sync pulses will be added to the selected video signal(s) to yield standard commercial EIA format video signal(s) by circuitry which will be included with each of the video coax switches in the ATM. The signal from each of the two video coax switches will be routed to the video coax switch of the television system of the SWS located in the MDA via coax cable which forms a part of the television system of the SWS where the video signal(s) will be conditioned to the proper voltage levels to be compatible with the S-band FM transmitter of the CSM.

1.3.4 Communications System of the Saturn IB Launch Vehicle

The Saturn IB Launch Vehicles used in missions SL-2, SL-3, and SL-4 will be equipped with the same VHF telemetry systems, UHF command-destruct systems, UHF up-data system, and C-band radar transponder systems as the operational Saturn IB Launch Vehicles used in the Apollo Program. As in the Apollo Program, the battery supplies associated with the communications systems of the IU and the S-IVB stage will be exhausted at approximately 7.5 hours after liftoff and these systems will cease to operate at that time.

1.3.5 Communications System of the Command and Service Module

The CSM's used in missions SL-2, SL-3, and SL-4 will be equipped with largely the same Unified S-Band (USB) communications system (with the exception of the S-band steerable antenna which will be deleted), VHF communications system, voice communications system, PCM telemetry system, data storage system, up-data system, VHF ranging system, and television system as the Block II CSM's used in the Apollo Program.

The communications functional capabilities provided simultaneously by the redundant PM transponders of the USB system include: (a) active range and range rate tracking assistance to the MSFN, (b) up-data reception from the MSFN, (c) real-time telemetry transmission to the MSFN, and (d) voice communications with the MSFN. The communications functional capabilities provided sequentially by the S-band FM transmitter of the USB system include: (a) television transmission to the MSFN, (b) simultaneous dump to the MSFN of recorded voice information and recorded PCM telemetry data, and (c) in a contingency mode transmission to the MSFN of real-time PCM telemetry data. One PM transponder and the S-band FM transmitter will be capable of simultaneous operation and will share the S-band antenna subsystem through a triplexer. The CSM S-band antenna subsystem will include four S-band antenna elements spaced approximately 90 degrees apart on the CM; however, only one element may be used at any given time. The CSM S-band antenna element to be used may be selected manually by a crewman or by command from the MSFN via the up-data system of the SWS or the up-data system of the CSM.

The communications functional capabilities provided on a time-shared basis by the VHF communications system of the CSM include: (a) voice communications with the MSFN and (b) VHF ranging of the SWS. The two VHF AM transceivers will share the VHF in-flight antenna subsystem through a triplexer. The VHF in-flight antenna subsystem will include two VHF antenna elements spaced approximately 180 degrees apart on the SM; however, only one element may be used at any given time.

Voice communications capability among the crewmen regardless of the location of each crewman (CM, SWS, or performing EVA) will be provided via the audio distribution hardline network in the SWS and the audio centers of the CSM, two of which will be used for bridging all audio signals from the microphone lines to the headset lines of the audio distribution hardline network in the SWS. Through appropriate switch settings on the various audio centers, the audio distribution hardline network may be connected to either the USB communications system or the VHF communications system or both to provide a voice communications link between the MSFN and a crewman located anywhere in the OA. The crewmen will have the capability to activate the selected S-band or VHF transmitter for voice transmission regardless of his location in the OA. A fixed speaker and microphone (speaker box) will be provided in the CM for use with the third audio center to serve in lieu of the PCS to provide the voice communications capabilities to a crewman located in the CM.

The PCM programmer of the PCM telemetry system of the CSM will sample all or a portion of the data available from the measuring subsystem in accordance either one of the two fixed built-in sampling programs providing an output PCM data stream of either 51.2 kbps or 1.6 kbps. Either one of these data streams will be suitable for transmission to the MSFN in real-time via the USB system or for storage by the CSM data storage system. It is planned that only the 1.6 kbps PCM data stream will ever be stored on-board during these Skylab Program missions. Experiments S071/072 carried and performed in the SM of mission SL-3 and experiment S061 carried and performed in the CM of mission SL-4 will each be provided with a separate autonomous data system to collect and store appropriate experiment data. In order to retrieve this stored experiment data, the data will be read out periodically from the experiment data storage subsystem and be included in the 51.2 kbps PCM data stream output from the PCM programmer of the CSM telemetry system.

The data storage system of the CSM may be used to store periodically voice communications present on the intercom bus of the audio centers and/or the 1.6 kbps PCM data stream output from the PCM programmer. When storing this information, the tape recorder of the data storage system will have a continuous record capability of two hours. The stored voice and PCM data will be dumped at a speed 32 times the record speed; however, the tape must be rewound before playback may be accomplished. The voice and data outputs from the playback electronics of the tape recorder will be routed to the S-band FM transmitter for transmission to the MSFN.

The up-data system of the CSM will be capable of detecting and decoding a PSK up-data message and of routing the commands to the proper location (relays, central timing equipment, or guidance computer) for action. The up-data system will determine whether or not the received up-data message was a valid CSM command (proper addresses and sub-bit encoding) and will provide a signal to the PCM telemetry system for transfer to the MSFN indicating receipt of a valid up-data message. The up-data system will have the capability to handle up to 32 set/reset commands.

The VHF ranging system of the CSM will enable the range between the CSM and a remotely located VHF ranging transponder to be established. The VHF ranging system will include a digital range generator (DRG) and will use the 259.7 MHz AM transmitter and the 296.8 MHz AM receiver of the VHF communications system of the CSM.

The television system of the CSM will include a refurbished color television camera and black and white monitor from the Apollo Program. This camera and monitor will be transferred to the SWS and will be used in conjunction with the video distribution network of the SWS. The video output of this camera will meet the standards for commercial black and white television signals contained in the EIA Standard RS170. It will be possible to transmit to the MSFN via the S-band FM transmitter either the output of this portable television camera directly when it is operated in the CM or the video signal which has been selected in the video distribution network of the SWS and routed to the CSM for transmission to the MSFN.

1.3.6 Communications System of the Crewmen

Each crewman will be equipped with a personal communications system (PCS) which will provide the capabilities for biomedical data collection and transfer and for voice communications. Regardless of the location of the crewmen (in the CM, in the SWS, or performing EVA), biomedical data transfer capability (including spacesuit data when applicable) and/or voice communications may be accomplished via hardline connections to the audio centers of the CM or to the communications panels of the audio distribution hardline network of the SWS.

2.0 DESCRIPTION OF SPACE VEHICLE MODULE COMMUNICATIONS SYSTEM

A description of the communications systems of the space vehicle modules and the interfaces between communications systems of these modules is included in the following paragraphs for each of the Skylab Program missions defined in Section 1.2.

2.1 Mission SL-1

The communications systems of the various space vehicle modules in Mission SL-1 are described in the following sections as designated below:

(a) Saturn V Launch Vehicle in Section 2.1.1,

(b) SWS in Section 2.1.2, and

(c) ATM in Section 2.1.3.

The radio frequency systems of the various modules in mission SL-1 are listed in Table 2.1.1. In this application of the Saturn V Launch Vehicle, the S-IVB stage will not be a powered stage and, consequently, will not carry the communications systems normally carried by the S-IVB stage of a Saturn V Launch Vehicle. All other stages and the IU of this Saturn V Launch Vehicle will carry essentially the same communications systems as carried by the respective stages and IU of the Saturn V Launch Vehicles used in the Apollo Program.

2.1.1 Communications System of the Saturn V Launch Vehicle

2.1.1.1 General

The communications systems of the Saturn V Launch Vehicle will provide the following functions:

(a) telemetry transmission to the Manned Space Flight Network (MSFN),

(b) command-destruct data reception from the Air Force Eastern Test Range (AFETR),

(c) up-data reception from the MSFN, and

(d) tracking aid to the MSFN and the AFETR.

The Saturn V Launch Vehicle normally consists of three powered stages (S-IC, S-II, and S-IVB) and the Instrument Unit (IU). However, in this application, the S-IVB stage will not be a powered stage and as a result will not be considered as part of the Saturn V Launch Vehicle for the purposes of this

TABLE 2.1.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-1

Location	System	Frequency (MHz) Transmit	Frequency (MHz) Receive	Modulation
S-IC	Telemetry	256.2		FM/FM
	Telemetry	244.3		PCM/FM
	Command-Destruct		450	FSK/FM
S-II	Telemetry	240.2		FM/FM
	Telemetry	232.9		FM/FM
	Telemetry	248.6		PCM/FM
	Command-Destruct		450	FSK/FM
IU	Telemetry	250.7		FM/FM
	Telemetry	245.3		PCM/FM
	CCS	2282.5	2101.8	PM
	C-Band Transponder	5765.0	5690.0	Pulse
SWS	Telemetry, Recorded Voice	230.4		PCM/FM, FM
	Telemetry, Recorded Voice	235.0		PCM/FM, FM
	Telemetry, Recorded Voice	246.3		PCM/FM, FM
	Up-Data		450	PSK/FM
	VHF Ranging	296.8	259.7	AM
ATM	Telemetry	231.9		PCM/FM
	Telemetry	237.0		PCM/FM
	Up-Data		450	PSK/FM

document. Block diagrams of the communications systems of the S-IC stage, S-II stage, and IU described in the following paragraphs are shown in Figures 2.1.1, 2.1.2, and 2.1.3, respectively.

2.1.1.2 Command and Communications System

Separate radio frequency (RF) links between the Saturn V Launch Vehicle and the MSFN or the AFETR will be utilized to provide each of the above functions except for the Command and Communications System (CCS) link from the IU which will be utilized to provide the tracking aid to the MSFN, the up-data reception from the MSFN, and the telemetry transmission to the MSFN functions. The CCS of the IU will include a PM transponder, a power amplifier and an antenna system. The PM transponder will include a receiver, an auxiliary oscillator, a phase modulator, a multiplier chain, a power supply, and associated equipment. The CCS will receive and transmit at S-band frequencies.

The CCS will be capable of receiving and detecting a stable component of a carrier frequency of approximately 2101.8 MHz and a baseband signal phase modulating the up-carrier composed of a pseudo noise (PN) range code and a 70 kHz subcarrier which may be frequency modulated with phase shift keyed up-data information. The 70 kHz subcarrier and the PN range code may be transmitted to the CCS simultaneously, separately, or not at all. The 70 kHz subcarrier will be demodulated by the CCS and the detected signal containing the coded up-data information will be routed to a command decoder in the IU. The noise figure of the receiver portion of the CCS will be a maximum of 13 dB.

The CCS will also be capable of generating and transmitting a carrier in phase coherence with but offset from the received carrier frequency by a constant ratio of 240 to 221, resulting in a transmitted frequency of nominally 2282.5 MHz. The carrier transmitted by the CCS may be supplied by the auxiliary oscillator of the CCS. When no S-band carrier is being received, the auxiliary oscillator will supply the carrier. Switching commands for selection of source of carrier frequency, auxiliary oscillator or derived from received carrier frequency, will be provided automatically by receiver automatic gain control signals. The CCS will phase modulate its transmitted carrier with the detected PN range code if it is present and with a 1.024 MHz subcarrier which will be phase modulated by a PCM telemetry signal from the PCM telemetry subsystem of the IU. The transmitted output of the CCS will be routed to a power amplifier for amplification. The output power of this power amplifier will be nominally 20 watts.

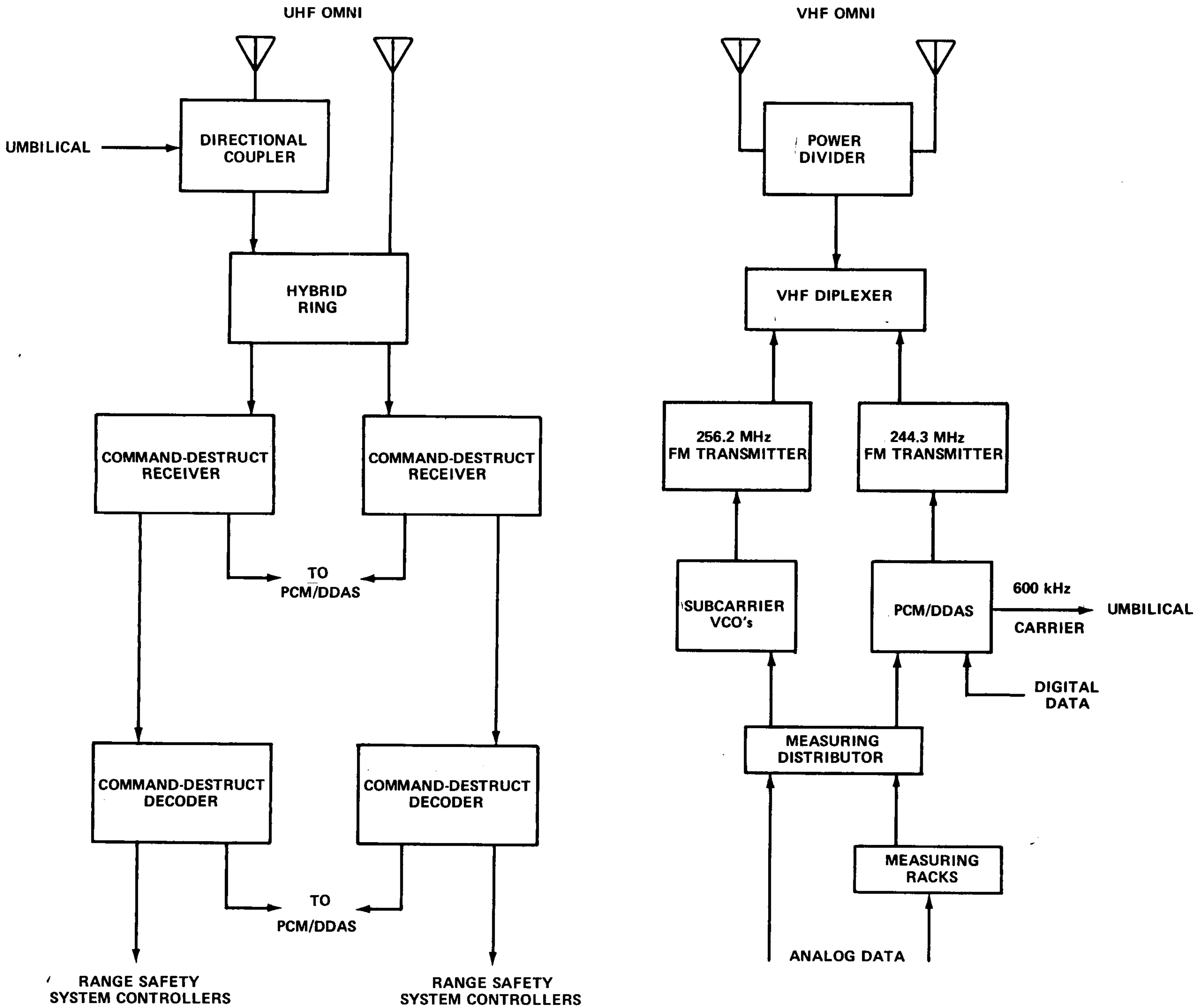

FIGURE 2.1.1 S-IC STAGE COMMUNICATIONS SYSTEM

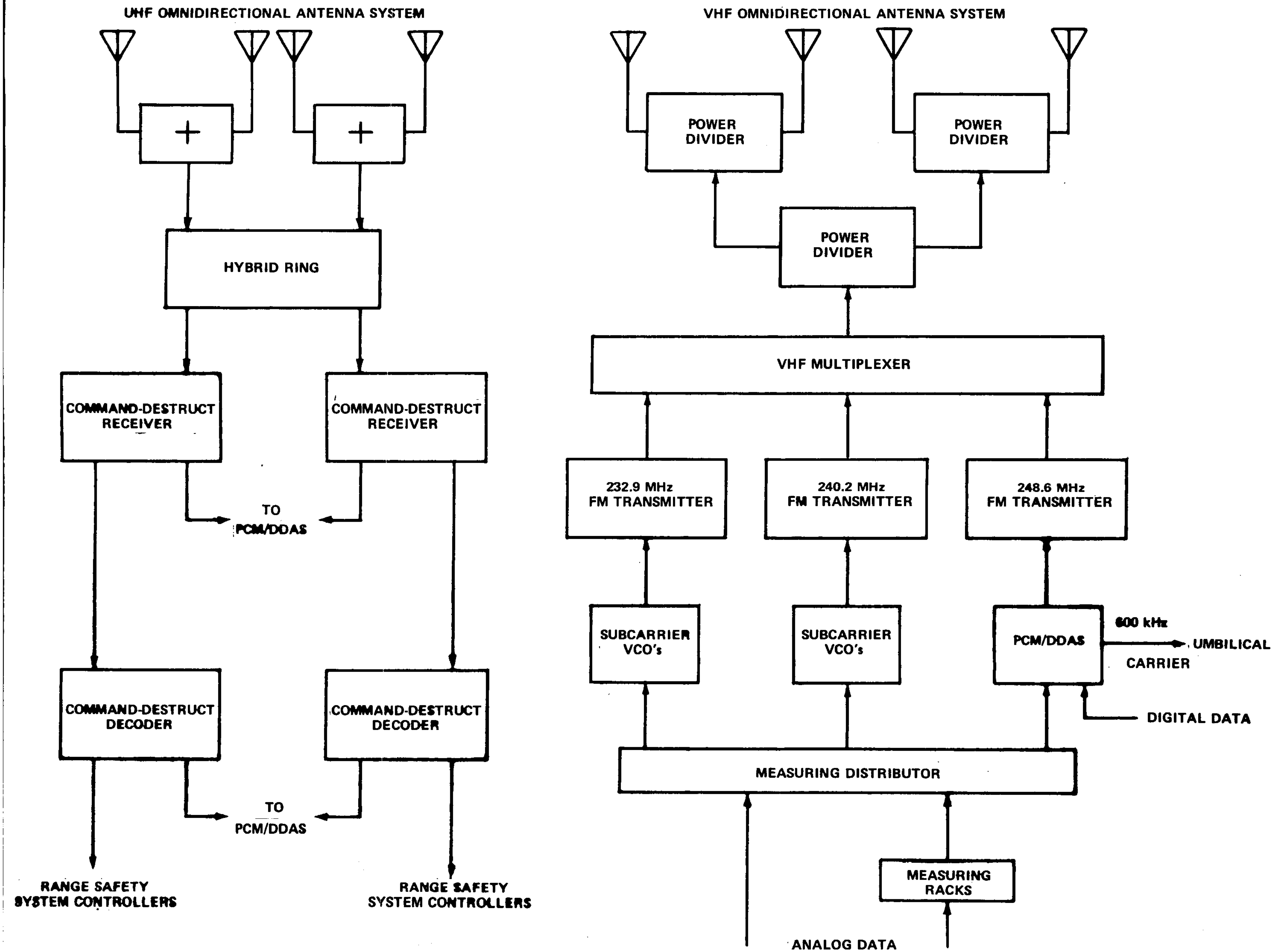

FIGURE 2.1.2 S-II STAGE COMMUNICATIONS SYSTEM

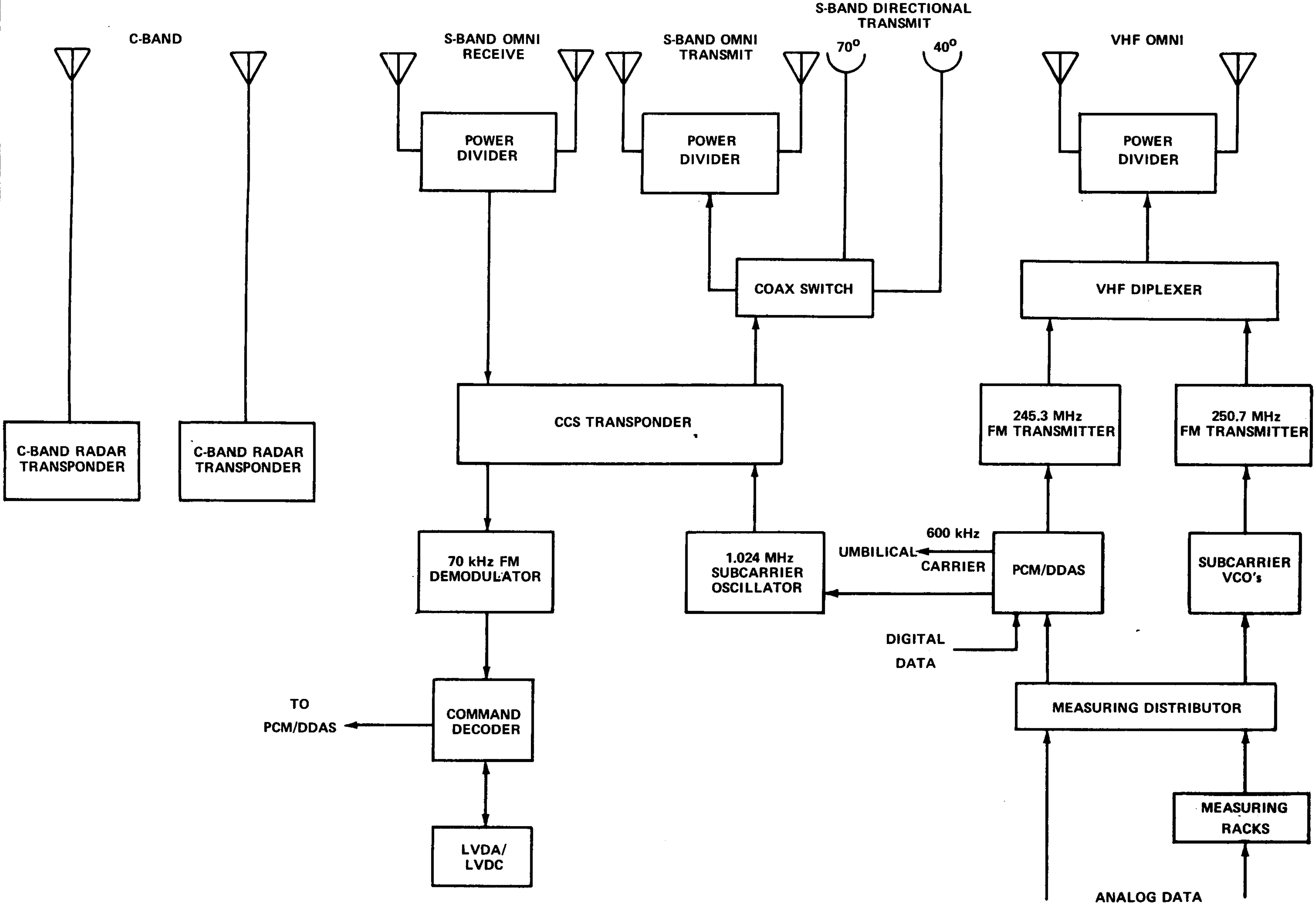

FIGURE 2.1.3 INSTRUMENT UNIT COMMUNICATIONS SYSTEM

The receiving portion of the CCS will be open and operating continuously until the CCS battery power supply in the IU has been exhausted (approximately 72 hours after liftoff). The transmitting portion of the CCS will be able to be turned on or off upon command from the MSFN via the CCS link to the IU.

The CCS antenna system will consist of one omnidirectional antenna subsystem for the receiver portion and one omnidirectional antenna subsystem and one directional antenna subsystem for the transmitter portion of the CCS. The receiver omnidirectional antenna subsystem operating in the 2090 to 2110 MHz frequency band will consist of two linearly polarized antenna elements located diametrically opposed on the IU. The received signal outputs from these two antenna elements will be coupled and hardwired to the receiver portion of the CCS. The transmitter omnidirectional antenna subsystem operating in 2250 to 2290 MHz frequency band will consist of two linearly polarized antenna elements located diametrically opposed on the IU connected through a power splitter so each will be driven with equal power. The transmitter directional antenna subsystem operating in the 2250 to 2290 MHz frequency band will consist of two independent sets of elements within a common outer covering, a single helix and a four element helix array. The directional antenna subsystem will be fixed with respect to the vehicle and will be neither mechanically nor electronically steerable. The single helix directional antenna will be circularly polarized in the right-hand sense and will provide gain of 7 dB with a half-power beamwidth of 70 degrees. The four helix array antenna will also be circularly polarized in the right-hand sense and will provide a gain of 12 dB with a half-power beamwidth of 40 degrees. The transmitter output from the CCS may be connected to any one of the three transmitter antenna subsystems described above through program control by the launch vehicle digital computer or by command from the MSFN to the IU via the CCS link.

2.1.1.3 Instrumentation and Telemetry

Each stage of the Saturn V Launch Vehicle (S-IC and S-II) and the IU will be equipped with an independent measuring and telemetry system. Two different modulation techniques (PCM/FM and FM/FM) will be used for RF transmissions to the MSFN. The instrumentation and telemetry systems of the Saturn V Launch Vehicle will include measuring subsystems, FM/FM telemetry subsystems, PCM telemetry subsystems, and RF transmission subsystems.

2.1.1.3.1 Measuring Subsystems

The measuring subsystem of each stage and IU will consist of sensors, transducers, and signal conditioning equipment. This subsystem will convert the quantities to be measured into electrical signals and will condition these signals as required to be acceptable to the FM/FM and/or PCM telemetry subsystems.

Analog electrical outputs from the sensors or transducers which have not been normalized (0 to +5 VDC full scale) will be routed to measuring racks which contain signal conditioning equipment. Each measuring rack will be capable of simultaneously normalizing 20 different input signals into electrical signals acceptable to the various telemetry systems. The outputs of the measuring racks and the outputs of sensors or transducers already normalized will be routed to measuring distributors which, in turn, will route the measurement signal to the proper telemetry subsystem subcarrier oscillators and/or analog multiplexer channels. A remote automatic calibration system (RACS) will be provided in the measuring racks to enable the various channels of the measuring subsystem to be calibrated remotely prior to launch. The RACS cannot be energized after liftoff.

Event and other digital signals will not require conditioning and will be routed to digital multiplexer assembly of the PCM telemetry subsystems.

2.1.1.3.2 FM/FM Telemetry Subsystems

The FM/FM telemetry subsystems of each stage and IU will be used for the transfer of analog data with bandwidth of up to 1 kHz and accuracies of from 1 to 2 per cent. These telemetry subsystems will conform to the Inter-Range Instrumentation Group (IRIG) Telemetry Standards for frequency division multiplexing (FM/FM) telemetry systems using proportional-bandwidth subcarrier channels. An analog signal will be routed from a measuring distributor of a stage to each voltage controlled oscillator (VCO) of the FM/FM telemetry subsystem(s) of that stage and be used to frequency modulate that subcarrier oscillator frequency. The combined output of several subcarrier VCO's (up to 18) will in turn be used to frequency modulate a RF transmitter of that corresponding stage. The combined output of several subcarrier VCO's (up to 8) may also be used to frequency modulate another subcarrier VCO whose output will be included in the combined output of several subcarrier VCO's which will frequency modulate a RF transmitter. In this manner, up to the maximum required 27 continuous analog channels can be provided by each FM/FM telemetry subsystem.

2.1.1.3.3 PCM Telemetry Subsystems

The PCM telemetry subsystems of each stage and IU will be used for the time division multiplexing of sampled narrow bandwidth data, data originating in digital forms, and the data on launch vehicle systems performance required on Earth for checkout and/or flight control of the launch vehicle. Each PCM telemetry subsystem will include, in addition to other assemblies, up to six pulse amplitude modulation (PAM) time division multiplexer assemblies (not including the remote analog submultiplexers), a scanner-timing assembly, an analog-to-digital converter assembly, and a digital multiplexer assembly (not including remote digital multiplexers). The remote analog submultiplexers (RASM's) which feed the PAM multiplexers and the PAM multiplexers will be synchronized by the scanner-timing assembly. The outputs of the various PAM multiplexers will be combined into a programmed sequence determined by the scanner-timing assembly and this sequence will be routed to the analog-to-digital converter assembly. The digital output of the analog-to-digital converter assembly will be combined with data originating in digital form and with synchronization words in the digital multiplexer assembly to form a NRZ-L PCM bit stream of 72 kilobits per second (kbps) which is a serial, binary-coded, non-return-to-zero, digital signal where a "one" is represented by one level and a "zero" is represented by another level. The 72 kbps NRZ-L PCM bit stream generated by the PCM telemetry subsystem of each stage and IU will be transmitted to the MSFN via one or more RF links from the corresponding stage or IU. Up to three different ways of combining the outputs of the PAM multiplexer assemblies may be programmed into the scanner-timer assembly, any one of which could be selected by command if the capability were utilized.

The PCM wavetrain generated by each PCM telemetry subsystem will be composed of words consisting of ten bits which will be arranged with the most significant bit appearing first. Ten bi-level or discrete channels will be grouped to form a single word. Data in digital word form with word lengths greater than ten bits (e.g. computer words) will be divided into groups of ten bits and the groups will be inserted in the PCM wavetrain in different word time slots. The last three words (30 bits) in each frame will be used for synchronization and identification.

2.1.1.3.4 Radio Frequency Telemetry Transmission Subsystems

The S-IC stage of the Saturn V Launch Vehicle will be equipped with two VHF FM telemetry transmitters, one for the transmission of the PCM wavetrain generated by the PCM telemetry subsystem of the S-IC stage and the second for the transmission of frequency multiplexed data composite generated by the FM/FM telemetry subsystem. The outputs of the two VHF telemetry transmitters of the S-IC stage will be multiplexed and will be fed simultaneously to two linearly polarized antenna elements located diametrically opposed on the S-IC stage and operating in 230 to 260 MHz frequency band.

The S-II stage of the Saturn V Launch Vehicle will be equipped with three VHF FM telemetry transmitters, one for transmission of the PCM wavetrain generated by the PCM telemetry subsystem of the S-II stage and the other two for the transmission of two different frequency multiplexed data composites generated by the FM/FM telemetry system. The outputs of the three VHF telemetry transmitters of the S-II stage will be multiplexed and fed simultaneously to four linearly polarized antenna elements located approximately 90 degrees apart on the S-II stage and operating in the 227 to 249 MHz frequency band.

The IU of the Saturn V Launch Vehicle will be equipped with two VHF FM telemetry transmitters and the CCS. The PCM wavetrain generated by the PCM telemetry subsystem of the IU will be routed in parallel to one of the VHF FM telemetry transmitters and to the CCS for transmission to the MSFN. The PCM wavetrain routed to the CCS will phase modulate the 1.024 MHz subcarrier transmitted by the CCS and its antenna system (see Section 2.1.1.2). The frequency multiplexed data composite generated by the FM/FM telemetry subsystem of the IU will be transmitted to the MSFN by the second of the two VHF FM telemetry transmitters. The outputs of the two VHF FM transmitters of the IU will be multiplexed and fed simultaneously to two linearly polarized antenna elements located diametrically opposed on the IU and operating in the 240 to 260 MHz frequency band.

The output power of the VHF transmitters used for the PCM/FM telemetry links will be 15 watts and the output power of the transmitters used for the FM/FM telemetry links will be 20 watts.

The PCM telemetry subsystems of the S-IC and S-II stages and the IU of the Saturn V Launch Vehicle will each be provided with a 600 kHz carrier to enable transmission of the PCM wavetrain from each stage and IU via coaxial cable to ground based checkout equipment during prelaunch activities. The 600 kHz carrier of each PCM telemetry subsystem will be frequency modulated by the 72 kbps NRZ-L PCM wavetrain generated by that subsystem.

2.1.1.4 Ground Command

2.1.1.4.1 Command-Destruct

Each powered stage (S-IC and S-II) of the Saturn V Launch Vehicle will be provided with an independent command-destruct system to permit the Range Safety Officer to initiate emergency flight termination and propellant dispersion for range safety purposes. Each command-destruct system will include two sets of identical, redundant command receivers and decoders which will be compatible with Range Safety Command transmitters of the AFETR.

The redundant command receivers located in the S-IC stage will share a common antenna system. The antenna system will include two linearly polarized antenna elements spaced approximately 180 degrees apart on the S-IC stage and operating in the 445 to 455 MHz frequency band. The redundant command receivers located in the S-II stage will share a common antenna system operating in the 445 to 455 MHz frequency range. This antenna system will include four linearly polarized antenna elements spaced approximately 90 degrees apart on the S-II stage. The capability will be provided to feed the redundant command receivers on each stage with a command-destruct test signal via coaxial cable during prelaunch activities. In addition during prelaunch activities, it will be possible to turn off the command-destruct system of each stage by means of an electrical signal transmitted through an umbilical connection to that stage.

The signal which will be transmitted from the stations of the AFETR will be a carrier frequency of 450 MHz which has been frequency modulated ($\pm$50 kHz peak deviation) by digital command-destruct data. The minimum sensitivity of the on-board receivers will be -93 dBm (corresponding to an intermediate frequency bandwidth of 340 kHz and a noise figure of 12 dB). The digital command-destruct messages which could be transmitted by the AFETR stations to the launch vehicle will consist of 11 characters, 9 for address and 2 for command. Each character will be composed of two simultaneous tones chosen out of an alphabet of seven tones. Thus, the digital command message will take the form of a multiple frequency shift keyed (FSK) signal.

The command receiver will detect the FSK/FM signal and route the tone pairs to the decoder. The decoder will determine whether the message has the proper time interval between successive tone pairs, has the proper address, and contains a valid command. Reception and decoding of a valid command by either of the two sets of identical, redundant command receivers and decoders carried on a stage will result in the commanded action. If a valid command message has been received by the command-destruct system of a stage, the decoders will provide an indication to the PCM telemetry subsystem of that stage for transfer to the MSFN indicating reception of a valid command message and will act upon that command. The two commands associated with the command-destruct system of each stage will be: (a) terminating thrust and arming of the destruct exploding bridgewire and (b) firing of the destruct exploding bridgewire for propellant dispersal. The command-destruct system of the S-II stage will be modified to accept and execute a command to deactivate the command-destruct system permanently.

2.1.1.4.2 Up-Data

The up-data system of the Saturn V Launch Vehicle will be located in the IU and will include the CCS transponder, a command decoder, the launch vehicle digital computer (LVDC), and the launch vehicle data adapter (LVDA). The up-data system will be used to up-date guidance information in the LVDC and to command certain launch vehicle, ATM, and SWS functions. The up-data signal consisting of a 1 kHz synchronization tone linearly combined with a 2 kHz tone phase shift keyed by a serial bit stream of 1000 bits per second (bps) will be stripped off of the up-data subcarrier by the CCS (see Section 2.1.1.2) and routed to the command decoder. Since each up-data bit will be encoded into five sub-bits and the up-data signal contains sub-bits, the up-data bits will be received at an effective rate of 200 bps. Each up-data word will be composed of 35 up-data bits or 175 sub-bits. The first 3 up-data bits of each word will be the vehicle address bits, 14 additional up-data bits distributed throughout the word will be the system or decoder address, and the remaining 18 up-data bits will be information bits.

The command decoder will demodulate the up-data signal routed from the CCS, will check the sub-bit encoding patterns, and will check the vehicle and system addresses in the up-data word. Upon receipt of an up-data word with the correct sub-bit encoding patterns and with valid vehicle and system addresses, the decoder will supply an indication (address verification pulse -AVP) to the PCM telemetry subsystem of the IU for transfer to the MSFN and will route the 18 information bits after decoding to the LVDC through the LVDA. The LVDC will perform an error check on these information bits. If no error is detected, the LVDC will execute the command and will supply an indication (computer reset pulse -CRP) to the PCM telemetry subsystem of the IU for transfer to the MSFN that it had received 18 information bits. The commands acted upon by the LVDC in this manner include the execution of pre-programmed routines, enter closed loop checkout, and execution of discrete launch vehicle system functions. For the case where the computer is to be up-dated (e.g. navigation up-date), the information bits entered into the LVDC from the decoder will be non-destructively read out and transferred to the MSFN via the PCM telemetry subsystem of the IU for comparison and verification on the Earth before this information will be used by the LVDC.

2.1.1.5 Tracking

In addition to the CCS (2.1.1.2) which can serve as a tracking aid to properly equipped stations of the MSFN, the IU will carry two C-band radar transponders, each of which has its own antenna system. Both transponders will be operating during the launch phase, but only one will be active at any one time during the Earth orbital coast phase as controlled by an inhibit function program in the LVDC which will automatically activate the transponder whose antenna is closest to the Earth.

Each transponder will be set to receive double pulse code interrogation from the Earth on a frequency of nominally 5690 MHz. If the code pulse spacing is 8 ± 0.1 microseconds, the transponder will reply with a single pulse after an appropriate delay on a frequency of nominally 5765 MHz. The transponder receiver will have a nominal sensitivity of -65 dBm with a half-power IF bandwidth of 10 MHz. The output of the transponder transmitter will be a minimum of 400 watts peak power with a maximum pulse repetition frequency (PRF) of 2000 pulses per second (PPS).

The antenna system of each C-band radar transponder will include a right-hand circularly polarized antenna element operating in the 5650 to 5800 MHz frequency band which will serve for both transmitting and receiving. The two antenna elements will be located on the IU and will be spaced approximately 180 degrees apart.

2.1.2 Communications System of the Saturn V Workshop

2.1.2.1 General

The SWS will be equipped with:

(a) an independent instrumentation and telemetry system for the transfer of crewmen and SWS systems status, SWS systems perfom ce, and experiment output data to the MSFN and for the on-board display of appropriate data for crew assessment of critical SWS system status,

(b) an independent up-data receiving and decoding system to permit the MSFN to exercise in the SWS real-time control of experiments, antennas, and system functions, and to provide hard copy printout of selected up-data information,

(c) a voice communications system to enable crewmen in the SWS to communicate with crewmen located in any of the other modules of the OA and/or with crewmen performing extravehicular activity (EVA),

(d) a television system to enable routing of video signals from a portable camera or the ATM closed circuit television system to the CSM, and

(e) a tracking aid system to assist the CSM during rendezvous of the CSM with the SWS.

The communications systems of the AM will be used to fulfill the communications requirements of the SWS (the AM, the OWS, and the MDA). A block diagram of the communications system of the AM described below is shown in Figure 2.2.1.

2.1.2.2 Voice Communications

The voice communications system of the SWS in conjunction with the voice communications system of the CSM will provide: (a) private duplex voice intercom among the crew members, (b) recording of voice communications on-board the AM for subsequent dumping to a station of the MSFN, and (c) recording of voice annotations by one crew member concurrently on a non-interference basis with voice intercom between the remaining crew members. All real-time voice communications between the crewmen and stations of the MSFN will be accomplished using the VHF and/or USB communications systems of the CSM through the audio centers of the CM. The voice communications system of the

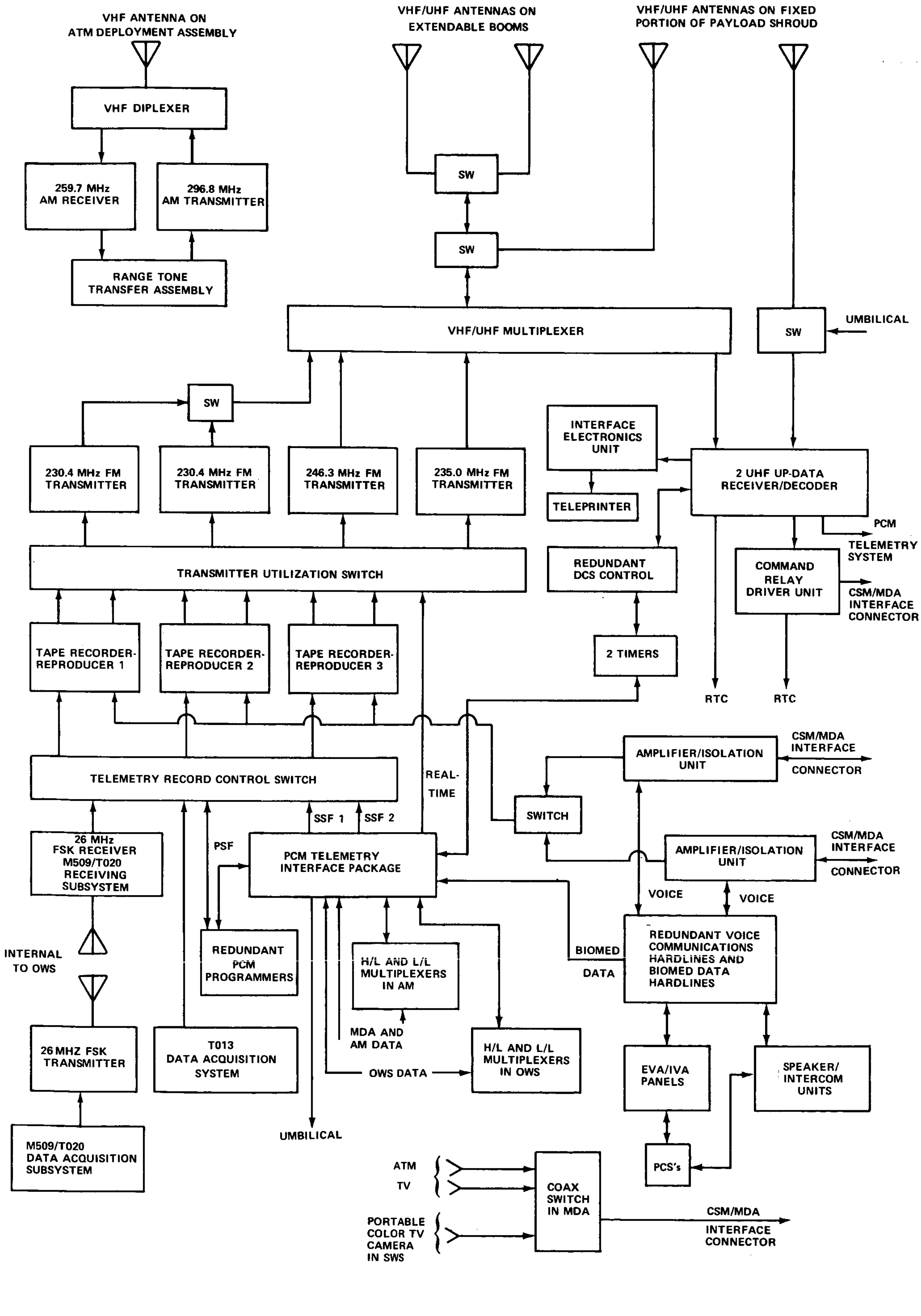

FIGURE 2.2.1 AIRLOCK MODULE COMMUNICATIONS SYSTEM

SWS will include an audio distribution hardline network and a tape recorder-reproducer subsystem and the RF transmitter subsystem which will be shared with the telemetry system of the SWS for transmission or recorder playback of stored voice information.

2.1.2.2.1 Audio Distribution Hardline Network

The audio distribution hardline network will include redundant and independent voice communications hardlines, an amplifier/isolation unit (or audio load compensator) in each hardline, and communications panels located for convenience in the various work and habitability areas of the SWS (2 in the MDA; 3 in the AM; 8 in the OWS).

The redundant voice communications hardlines will be routed in parallel but will be contained in separate cables and will use different connectors at module interfaces. An umbilical disconnect in each of the redundant hardlines will be provided on each communications panel. These umbilical disconnects will be compatible with the appropriate electrical umbilical assemblies of the personal communication system (PCS) of each crewman. It will be possible for the PCS's of two crewmen to be connected to the audio distribution hardline network simultaneously at one communications panel, one at each of the two umbilical disconnects. Support for all required functions of the PCS of a crewman (e.g., headset, microphone, dc power, biomedical data, transmitter key, etc.) will be available at each of these umbilical disconnects. Ring or closed loop wiring techniques will be used in installation of each of the redundant voice communications hardlines in the OWS.

All of the displays and controls on the communications panels in the SWS will be identical except for the panel located in the airlock area of the AM and the panel located in the Structural Transition Section (STS) of the AM. These two panels will be used solely to provide communications support to suited crewmen performing EVA or IVA and, as a consequence, none of the controls and displays provided on the other panels will be required except the associated power switches for each umbilical disconnect. These two communications panels are called EVA/IVA panels while the rest of the panels are called speaker/intercom units.

A fixed speaker and microphone will be incorporated in all of the speaker/intercom units in the SWS. The fixed microphone and speaker of each unit may be used in conjunction with either one of the audio distribution hardlines as determined by a crewman via a switch on the unit to provide a simplex voice communications capability. Any number of the fixed microphone and speaker units may be active simultaneously.

In addition, the following controls will be provided on the speaker/intercom units to enable the crew to operate the fixed speaker and microphone:

(a) a volume control to enable the crew to regulate the speaker output level,

(b) a channel select switch to enable the crew to operate the fixed speaker and microphone on either one of the two hardlines or to operate the speaker in the "sleep" mode (caution and warning system alarm signals will not override the "sleep" switch), and

(c) a speaker/microphone mode switch to enable the crew to operate the fixed speaker and microphone in a push-to-talk (PTT) mode (connects the microphone to the intercom bus and disconnects the speaker), in a listen only mode (connects the speaker to the intercom bus), or in a push-to-transmit (PTX) mode (connects the microphone to the intercom bus, disconnects the speaker, and enables an RF transmitter previously selected in the CSM for voice transmission to the MSFN.

A switch will be associated with each umbilical disconnect on the speaker/intercom unit to enable the crewman to configure the speaker/intercom units to be compatible with the mode of operation of the PCS selected by the crewman. These switch positions include:

(a) IC/PTX (Microphone and earphones of the PCS will be connected to the intercom bus and operation of the PTX switch of the PCS will enable an RF transmitter in the CSM.)

(b) PTT/PTX (Earphones of the PCS will be connected to the intercom bus and operation of the PTT switch of the PCS will connect the microphone of the PCS to the intercom bus and operation of the PTX switch of the PCS will connect the microphone to the intercom bus and enable an RF transmitter in the CSM.)

(c) Sleep (Microphone and earphones of the PCS will be disconnected from the intercom bus, but caution and warning system (CWS) signals will be allowed to pass through the umbilical disconnect.)

(d) Off (All dc power will be removed from disconnects and headset lines and CWS signal lines will be opened.)

A control will be provided on all speaker/intercom units to permit the crew to enable or inhibit storage of audio signals present on one of the two audio distribution hardlines. The selection of the hardline from which the audio signal will be taken for storage can be accomplished by crew operation of a switch on the control and display panel in the AM. A display will be provided on all speaker/intercom units to give the crew a visual indication when audio signals are being recorded.

A crew call switch (momentary) will be provided on all speaker/intercom units. Operation of the crew call switch will result in the interconnection of the microphone lines of the two independent voice communications hardlines, overriding of the "sleep" mode of the fixed speakers of the speaker/intercom units, and the enabling of the alarm tones of the caution and warning system of the SWS which will energize the speakers and the earphones of the PCS's. Release of the momentary crew call switch will result in the reversal of the actions described above. A crew alert command sent by a station of the MSFN via the up-data system of the AM will result in the same actions as activation of the crew call switch on the speaker/intercom units. Interconnection of the microphone lines of the independent voice communications hardlines will be accomplished in the SWS during crew call.

The amplifier/isolation unit included in each voice communications hardline will provide the interface between the hardline and an audio center of the CM, provide dc isolation of the CM audio center from the hardline, provide a constant impedance to the CM audio center, maintain constant audio levels, provide a separate audio output suitable for recording, and provide suitable audio signal levels to the communications panels in the SWS and the AM tape recorder-reproducer subsystem. The active portions of each amplifier/isolation unit will be parallel redundant. A separate amplifier in each amplifier isolation unit will be used to feed audio signals to the AM tape recorder-reproducer subsystem as required.

All electrical wiring, speaker/intercom units, EVA/IVA panels and amplifier/isolation units associated with the voice communications system of the SWS will be preinstalled. The speaker/intercom units in the OWS will be interchangeable and jumpers will be provided to enable a faulty speaker/intercom unit in the SWS to be removed permanently.

2.1.2.2.2 Tape Recorder-Reproducer Subsystem

The type of tape recorder used in the tape recorder-reproducer subsystem described in more detail in Section 2.1.2.3.3

will be a two-track tape recorder of the basic Gemini design with only one track to be used for recording PCM data. The record and reproduce electronics for the second track of the recorder have been modified to enable voice signals (300 to 3000 Hz) to be recorded and later played back at a tape rate 22 times faster (6600 to 66,000 Hz) than the record rate although in reverse. Voice signals present on the selected audio distribution hardline will be simultaneously recorded on the second track of all recorders of the tape recorder-reproducer subsystem that are running at any given time. However, a crew member will be provided with the capability of inhibiting voice signals on the audio distribution hardline from the recorders by operating a switch located on each of the speaker/intercom units. Time reference for the voice signals will be contained in the PCM data recorded on the first track of the various recorders. Therefore, playback and transmission to the MSFN of the telemetry and voice data recorded on one recorder must be simultaneous to enable time correlation of voice signals with mission events.

2.1.2.2.3 Radio Frequency Transmitter Subsystem

Playback of the voice data stored by the tape recorder-reproducer subsystem of the AM will be transmitted to stations of the MSFN by the RF transmitter subsystem of the AM. The RF transmitter subsystem of the AM and the modes of operation of this subsystem are described in Section 2.1.2.3.4.

2.1.2.3 Instrumentation and Telemetry

The AM will be provided with an independent measuring and telemetry system. The MDA and the OWS will each be provided with an independent measuring system, but will share the telemetry system of the AM for the transfer of data to the MSFN. However, a remote automatic calibration system (RACS) will be provided in the OWS to enable the various channels (transducers and/or signal conditioning modules) of the OWS measuring system to be calibrated remotely during launch. The RACS cannot be energized after liftoff. In addition, an umbilical hardline capability will be provided in the OWS for routing 23 analog red-line measurements and an undetermined (up to 300) number of red-line event indications directly to the launch facilities. These red-line measurements will also be routed to the telemetry system of the AM.

Data, both analog and digital, from sensors or transducers located in the MDA and the OWS which will require display in the AM and/or transmission via the telemetry system of the AM will be conditioned prior to transfer via hardline to the AM telemetry system. The digital signal voltages from sensors and signal conditioning equipment will be restricted to a few discrete levels and the analog signal voltage range from sensors and signal conditioning equipment will be normalized to extend from 0 to 5 volts full scale or from 0 to 20 millivolts full scale or differential in order to be compatible with the remote multiplexers used by the AM telemetry system. The major portion of the data gathered in the OWS will be routed to remote multiplexers located in the OWS; however, data requiring high sampling rate channels will be hardwired to the AM telemetry system for direct insertion. All of the data gathered in the MDA will be routed to multiplexers located in the AM. It is planned to divide the bi-level measurements in the MDA into groups of three and combine each group of three measurements in such a manner that the data can be inserted in an analog channel of the AM telemetry system. Outputs from sensors located in the AM will be similarly conditioned by the signal conditioning equipment in the AM prior to transfer to the multiplexers of the AM telemetry system. The signal conditioning equipment will also convert appropriate signal inputs into signals which will activate lights and provide discrete closures to the AM CWS. All electrical wiring in the MDA, AM and OWS will be preinstalled.

Each crewman will wear a vest equipped with biomedical sensors, appropriate transducers, and signal conditioners to provide electrocardiogram (ECG), heart rate, impedance pneumograph (ZPN), and body temperature measurements as well as identification of the crewman. These signals will appear on five pairs of wires (five channels) included in the electrical umbilical assembly of the PCS of each crewman. These signals will be transferred to the telemetry system of the AM via two biomedical data hardlines branched into the MDA, the AM, and OWS. Each of these hardlines will be routed in parallel with a different one of the two voice communications hardlines of the audio distribution hardline network and will share the umbilical disconnects of the respective voice communications hardlines. These disconnects will be compatible with the electrical umbilical assembly of the PCS of the crewmen. The two biomedical data hardlines will be routed in a manner that will permit biomedical data transfer from two crewmen to the AM telemetry system only for the case when the PCS's of the two crewmen are connected to different biomedical data hardlines. Otherwise, the biomedical data from both crewmen will be superimposed.

In addition to the hardlines which will also be provided between all speaker/intercom units and EVA/IVA panels and the AM telemetry system for transfer of biomedical data from two crewmen, hardlines will be provided from the EVA/IVA panels in the STS and the airlock of the AM to the AM telemetry system for the transfer of suit internal environment data from two crewmen.

The telemetry system of the AM will include a multiplexer and PCM encoder subsystem, autonomous experiment data systems, a tape recorder-reproducer subsystem, and an RF transmitter subsystem.

2.1.2.3.1 Multiplexer and PCM Encoder Subsystem

The multiplexer and PCM encoder subsystem of the AM will include high level (H/L) and low level (L/L) multiplexers (some of which will be located remotely in the OWS and MDA), a PCM interface package or interface box (IB), and redundant PCM programmers each with its own analog-to-digital converter, sync generator, timing generator, etc. This subsystem will be capable of combining and converting the analog and digital signals received from the measuring subsystems of the MDA, AM, and OWS and from the PCS's of up to two crewmen into a serial binary coded digital (PCM) signal of 51.2 kbps. Separate outputs from the multiplexer and PCM encoder subsystem will be supplied to route this PCM signal to the RF transmitter subsystem and to route this PCM signal to an umbilical hardline through the forward skirt of the OWS for use during prelaunch checkout. Three different subsets of this PCM signal, each consisting of 5.12 kbps, will be extracted and will be converted to return-to-zero (RZ) PCM signals for routing to the tape recorder-reproducer subsystem for storage. The programmer will internally provide analog data multiplexing functions, an analog-to-digital conversion function, a digital data multiplexing function, required timing and control functions for external multiplexers, and some input gates for high sampling rate channels. The PCM IB adapts the programmer to accept the addition of more H/L and L/L multiplexers and more low sampling rate channels. The PCM IB will be designed to accept 37 multiplexers, 18 H/L, and 19 L/L multiplexers. Each H/L multiplexer will accept as data inputs a maximum of 32 high level (0 to 5 VDC), 24 bi-level, and 16 bi-level pulse signals. Each L/L multiplexer will function as a differential analog commutator and amplifier and will accept as data inputs 32 low level (0 to 20 millivolts differential) analog signals. The PCM IB will provide the necessary buffering for control lines and the power required to drive the remote multiplexers whose outputs are routed to the PCM IB. In addition, the PCM IB will make available a buffered 24-bit timing word output for use as required by experiments carried by the SWS. The PCM IB will contain dual redundant electronics.

The redundant electronic timers used in the AM up-data receiver and decoder unit redundancy control subsystem (see 2.1.2.4.2) will be used as part of the AM instrumentation and telemetry system to provide timing words to the multiplexer and PCM encoder subsystem which includes a 24-bit buffer register.

Two vehicle elapsed time parameters, fine time and coarse time, will be included in the output PCM signals from the multiplexer and PCM encoder subsystem, both the real-time 51.2 kbps PCM signal and three recordable 5.12 kbps PCM signals. The fine time word will be an 8-bit word which will be sampled 10 times per second indicating a time from 0 to 32 seconds in 0.125 second increments. The coarse time word will be a 24-bit word which will be sampled once every 2.4 seconds indicating a time from 0 to approximately 24.2 days in 0.125 second increments. As indicated above, the 24-bit coarse time word will be available for parallel presentation from the PCM IB to experiments in the SWS as required and will be up-dated once each 0.125 second. The electronic timers and consequently the coarse time word presented to the AM multiplexer and PCM encoder subsystem and subsequently that made available to experiments in the SWS will be recycled to zero every 24.2 days or be reset to zero at any time by command. A portable electronic timer with a countdown and an alarm capability will also be included in the SWS; however, no means will be provided to interface this portable timer with the AM multiplexer and PCM encoder subsystem.

The PCM programmer will provide the timing for and control of the remote multiplexers, provide analog-to-digital data conversion, and combine the analog and digital data routed to the PCM IB from remote multiplexers or directly from signal conditioning packages and synchronization words to form a serial PCM wavetrain. The PCM programmer PCM data stream output will be a serial binary coded non-return-to-zero level (NRZ-L) signal of 51.2 kbps composed of words consisting of eight data bits arranged with the most significant bit appearing first. Bi-level data and digital data will be grouped in blocks of eight consecutive bits. Each PCM programmer will have a single fixed format program which cannot be changed as a function of mission phase unless physically rewired. The data cycle rate in the format will be once per 2.4 seconds. The redundant PCM programmers may be selected manually by the crew or by the MSFN via the up-data system of the AM through the PCM IB. All housekeeping data required by the Mission Control Center (MCC) for mission control covering those periods of the mission when the SWS will not be within line-of-sight of a station of the MSFN, all digital data, and data from some of the on-board experiments will be time-division multiplexed into the prime subframe (one of the ten 640 sps channels available in the PCM telemetry format) of the PCM telemetry format by the PCM programmer. That portion of the real-time 51.2 kbps NRZ-L PCM data stream output from the PCM programmer corresponding to the primary subframe will be extracted by the PCM programmer and will be converted into a return-to-zero (RZ) PCM data stream of 5.12 kbps. This 5.12 kbps RZ PCM data stream will be provided as an output from the PCM programmer and will be suitable for storage by the tape recorder-reproducer subsystem.

The PCM IB will contain the necessary circuitry required to create four secondary subframes out of four of the ten 640 sps channels available in the format of the PCM programmer. Those portions of the real-time 51.2 kbps NRZ-L PCM data output from the PCM programmer which correspond to three of the four secondary subframes created by the PCM IB will be extracted by the PCM IB and will be converted into three separate (each corresponding to a different one of the three secondary subframes) 5.12 kbps RZ PCM data streams. These three 5.12 kbps RZ PCM data streams will be provided as outputs from the PCM IB and will be suitable for storage by the tape recorder-reproducer subsystem.

These four 5.12 kbps RZ PCM data streams which appear as outputs from the PCM IB and the PCM programmer (corresponding to three secondary subframes and the primary subframe, respectively) will each contain a synchronization word, a frame identification word, an address word, and elapsed time words which will enable the data contained in each of the subframes to be time correlated with mission events. Although all of these four data streams could be recorded if desired, in practice only the PCM data streams corresponding to the primary subframe and two of the three secondary subframes can be routed to the AM tape recorder-reproducer subsystem for storage during the mission. The PCM data stream corresponding to the third secondary subframe can never be recorded on-board the SWS during the mission because the necessary wiring and switching capabilities will not be provided in the AM.

Of the two secondary subframes which can be recorded on-board the AM, one secondary subframe will be composed of two 320 sps channels which will be used for two of the three electrocardiogram (ECG) measurements performed during experiments M093 (Vectorcardiogram) and M092 (In-Flight Lower Body Negative Pressure). The other secondary subframe will include one 320 sps channel used for the third ECG measurement obtained from M092 or M093 or the rotating litter chair current measurement from M131 (Human Vestibular Function Assessment) or the one ECG measurement from M171 (Metabolic Activities), one 40 sps channel used for an impedance pneumograph (ZPN) measurement, and the other channels necessary to accommodate the remaining data from experiments M092, M093, M131, and M171 when being conducted. All data from these medical experiments will be hardlined from the experiment into the Experiment Support System (ESS) mounted in the OWS where the data will be conditioned and routed to the PCM IB. The ECG and ZPN measurements will be routed to the PCM IB in analog form while all other data from these medical experiments will be routed to a multiplexer mounted external to the pressure shell of the SWS where it will be time-division multiplexed into a single pulse amplitude modulated signal before being routed to the PCM IB. In addition to providing the interface between the AM telemetry systems and experiment data for the medical experiments, the ESS will provide controls and displays for these experiments as well as other support including supply of fluids, vacuum, and power. Suitable connections for data, fluids, vacuum, and power transfer requirements to support the ESS will be provided in the OWS. It should be noted that the biomedical harness or vest worn by a crewman during the conduct of these medical experiments will be different from the biomedical harness which forms a part of the PCS of each crewman which is used to provide operational biomedical data on the crewman.

The two 320 sps channels of one of the recordable secondary subframes will be time-shared by the medical experiments as discussed above and by experiments T027 (Contamination Measurement) for collection and transfer of photometer data, S073 (Gegenschein/Zodiacal Light), and S149 (Particle Collection). A crewman must select via manual switching the data from which of these experiments will be routed to the PCM IB to fill these two 320 sps channels in the PCM telemetry format. Also in order to meet data retrieval requirements, the high sampling rate channels in the other recordable secondary subframe will be time-shared under crewman control by the medical experiments as discussed above and by experiments T027, S073, S149, and M508 (EVA Hardware Evaluation).

2.1.2.3.2 Autonomous Experiment Data Systems

Separate and autonomous data systems will be provided to support the following three groupings of experiments: (a) experiments M509 and T020, on a time-shared basis, (b) experiment T013, and (c) the Earth Resources Experiments Package (EREP). The data system supporting experiments M509 and T020 and the data system supporting experiment T013 are similar and will be described in the same section.

2.1.2.3.2.1 Experiments M509 and T020 and Experiment T013

A radio frequency experiment support subsystem will be provided to support experiments M509 (Astronaut Maneuvering Equipment) and T020 (Foot-Controlled Maneuver Unit) in order that the necessary portions of these experiments which must be performed with the crew member free of all tethers can be conducted without an umbilical connection for the transfer of data.

This subsystem will be divided into a small portable data acquisition and transmission subsystem which will be carried in a backpack by the crewman performing one of these experiments and a fixed mounted receiving subsystem. For the most part, the measuring subsystems including sensors, transducers, and signal conditioning equipment used to support both experiments will be the same. The major difference will be that data on the operation of a foot-controlled maneuvering unit will be gathered during experiment T020 while data on the operation of a hand-held maneuvering unit will be gathered during experiment M509.

The data acquisition and transmission subsystem will include a PCM programmer, a clock pulse generator, an analog-to-digital converter, a radio frequency transmitter, an antenna, and a power supply. The data acquisition portion of this subsystem will combine the experiment data from the measuring subsystem of the connected experiment into a serial binary coded digital (NRZ-M PCM) signal of 5.76 kbps. The NRZ-M PCM signal will be composed of words or groups consisting of eight bits, the most significant bit appearing first. A 24-bit synchronization code group will be included in every prime frame. The prime frame rate will be 10 frames per second. The data cycle rate will be 10 times per second corresponding to the prime frame rate for experiments M509 and T020. This NRZ-M PCM signal will be routed to the transmission portion of this subsystem. The transmitter will be a frequency shift-keyed (FSK) type and will operate at two crystal controlled frequencies, 25.925 MHz and 26.075 MHz, which will be keyed by the PCM signal as appropriate. The output power of this transmitter will be 10 milliwatts. The antenna used by this subsystem will be a slot type which will be flush mounted on the back pack worn by the crewman performing the experiment.

The receiving subsystem which will be fixed mounted in the OWS will include 2 antennas, a receiver, and a system-data synthesizer. The 2 slot antennas will be mounted perpendicularly but separated to provide circular polarization to ensure signal reception regardless of orientation of the transmitter antenna with respect to the receiver antennas. The receiver will be an FSK receiver with a narrow intermediate frequency bandwidth and a sensitivity of -117 dBw (20 microvolts). The 5.76 kbps NRZ-M PCM data stream generated by and transmitted from the data acquisition and transmission subsystem will be retrieved by the receiving subsystem and a 24-bit timing word will be inserted into the proper time slots in the detected 5.76 kbps NRZ-M PCM data stream which had been left blank. The resultant 5.76 kbps NRZ-M PCM data stream will be converted in the receiving subsystem into a 5.76 kbps RZ PCM signal which will be routed to the tape recorder-reproducer subsystem of the AM for storage.

Experiment T013 (Crew-Vehicle Disturbance) will use a data acquisition subsystem similar to that used for experiments M509 and T020. The crew member performing experiment T013 will be equipped with a limb motion sensing subsystem which enables direct measurement of limb position. This data is routed through an umbilical connection to a fixed mounted data acquisition subsystem where it will be combined with data from a force measuring subsystem and with a 24-bit timing signal and with synchronization words to form a NRZ-L PCM signal of 5.76 kbps structured into 8 bit words, the most significant bit appearing first. This PCM signal will be converted by the data acquisition subsystem into a RZ PCM signal which will be routed to the tape recorder-reproducer subsystem of the AM for storage.

Since experiments M509, T013, and T020 will never be conducted simultaneously, the tape recorder-reproducer subsystem of the AM will be required to record at most only one of these 5.76 kbps RZ PCM signals at any given time. A crew member must manually select which of these RZ PCM signals will be recorded -- the signal from the data acquisition subsystem shared by experiments M509 and T020, the signal from the data acquisition subsystem of experiment T013, or none of these. In no event will the PCM signals generated by these data acquisition subsystems be transmitted to the MSFN in real-time, nor will data from these experiments be incorporated into the 51.2 kbps NRZ-L PCM signal generated by the multiplexer and PCM encoder subsystem of the AM (see Section 2.1.2.3.1).

2.1.2.3.2.2 Earth Resources Experiments Package

All of the experiment data from the EREP will be handled by the EREP data system and will finally be recorded on magnetic tape or film which will be subsequently returned to Earth in the CM. As currently planned, no EREP peculiar data will be included in the real-time or delayed-time PCM data streams transmitted from either the SWS or the ATM to the MSFN. In fact, the only planned data interface between the EREP and the OA will be for the purpose of transferring mission elapsed time data from the ATM to the EREP.

The data system of the EREP will include a number of separate measuring and data formatting subsystems -- one associated with each of the experiments, a number of VCO's and a 28-track tape recorder. Data will be outputted from the measuring and data formatting subsystem of each of the various experiments in a form suitable for storage on film or on magnetic tape. Data from each of the various experiments to be stored on magnetic tape will be outputted in the form of one or more serial digital bit streams. Each of these digital signals will be routed to the 14-track tape recorder and will be stored on separate tracks except in a few instances where two or more low bit rate digital signals will be frequency multiplexed prior to storage on one of the 14 tracks. In each of these instances, the appropriate digital signals will frequency modulate different VCO'S and the modulated outputs of the VCO's will be combined and routed to the record electronics for one of the tracks of the tape recorder. Consequently, the tape recorder must use both digital and FM recording techniques. The mission elapsed time data received by EREP from the Workshop Computer Interface Unit (WCIU) will be recorded on one of the tracks of the magnetic tape and will provide the time reference for all of the experiment data stored on the various tracks of the magnetic tape.

When the data from the multispectral IR imager experiment is being recorded, a record tape speed of 60 ips will be required because of the bandwidth occupied by the data. During other periods of EREP activation, a record tape speed of 7.5 ips will be sufficient. The crew will be provided with the capability to change the magnetic tape reel of the tape recorder.

2.1.2.3.3 Tape Recorder-Reproducer Subsystem

The tape recorder-reproducer subsystem of the AM will include three fixed mounted tape recorders of the type used in the Gemini Program which will be electrically wired to permit simultaneous operation. For reliability reasons, the crew will be provided with the capability to replace physically any one of the fixed mounted recorders in the event of a failure of that recorder. Each of the recorders will be a two-track recorder whose record electronics permit recording at least a 6.0 kbps RZ PCM bit stream on one track and recording a voice signal (300 to 3000 Hz) on the second track. Each tape recorder will be capable of providing a maximum of four hours of continuous recording time. Upon command, each recorder will rewind the recorded tape at 22 times faster than the tape speed during recording (1 7/8 ips) and read out the recorded PCM bit stream and the recorded voice signal simultaneously. The outputs of the recorder reproduce electronics will be a NRZ-S (non-return-to-zero-space where "one" is represented by no change in level and "zero" is represented by a change in level) PCM bit stream at an apparent rate of 22 times greater than the recorded rate resulting in PCM data rates of either 112.64 or 126.72 kbps and a voice signal with all frequency components increased by a factor of 22. The recorded information will not be erased from the tape during the playback mode thereby permitting a redump of recorded information if required. A fast forward (same forward tape speed as playback tape speed) tape wind mode of operation without erasing the tape will also be provided in each recorder which may be selected manually by the crew or remotely by the MSFN via the up-data system of the AM. Upon removal of the playback command in the absence of any other related command, the tape recorder will automatically be switched into the record mode.

Switching will be incorporated to enable the crew to route any of the PCM data streams to be stored (the prime subframe and two secondary subframes from the multiplexer and PCM encoder subsystem of the AM and the data from experiments T013, M509, and T020) to any of the three tape recorders of the tape recorder-reproducer subsystem. Thus, each recorder could be time-shared by as many as six PCM bit streams. Voice signals from the audio distribution hardline network of the SWS will be recorded simultaneously by all recorders which happen to be running. All switching functions in the tape recorder-reproducer subsystem of the AM may be accomplished by the on-board crew or if the crew permits, by the MSFN via the up-data system of the AM. The switch provided for use by a crewman on each of the speaker/intercom units when plugged into the umbilical disconnect of the audio distribution hardline network will activate or deactivate latching relay circuits which control the audio signal input to the recorder from the amplifier/isolation units of the audio hardline network and will activate a recorder to store the audio signal if none is in operation.

2.1.2.3.4 Radio Frequency Transmitter Subsystem

The RF transmitter subsystem of the AM will consist of four wideband FM (up to ± 100 kHz peak deviation) transmitters operating in the VHF telemetry frequency band. Three of the four VHF telemetry transmitters with carrier frequencies of 230.4 MHz, 235.0 MHz, and 246.3 MHz, respectively, will be used only during prelaunch checkout and Earth orbital coast phases of the SWS mission in order to avoid possible damage to these transmitters caused by high voltage breakdown of the air in the vented transmitter packages at critical pressures encountered during portions of the launch phase. The output power of each of these three transmitters will be ten watts minimum. The fourth VHF telemetry transmitter will be a two-watt transmitter and will operate with the same carrier frequency (230.4 MHz) as one of the three ten-watt transmitters. The two-watt transmitter can be switched to replace this ten-watt transmitter via the up-data system of the AM and will be used to transmit the real-time 51.2 kbps NRZ-L PCM data output from the multiplexer and PCM encoder subsystem of the AM during the launch phase. The two-watt transmitter will normally be deactivated during Earth orbital coast phases of the SWS mission and the corresponding ten-watt transmitter will be activated.

During Earth orbital coast, the three ten-watt transmitters will be capable of simultaneous operation on a non-interference basis. The three transmitters and one of the up-data receiver and decoder units will share a portion of the antenna system of the AM through use of a quadriplexer. (The two-watt and the ten-watt VHF transmitters which have the same carrier frequency will share one port of the quadriplexer via a coax switch.) The three transmitters will enable simultaneous transmission of any three of the following sources:

(a) real-time 51.2 kbps NRZ-L PCM bit stream,

(b) playback of PCM signal stored on one track of the first recorder,

(c) playback of voice signal stored on second track of the first recorder,

(d) playback of PCM signal stored on one track of the second recorder,

(e) playback of voice signal stored on second track of the second recorder,

(f) playback of PCM signal stored on one track of the third recorder, and

(g) playback of voice signal stored on second track of the third recorder.

The playback PCM signal outputs from the tape recorder-reproducer subsystem will be NRZ-S PCM bit streams of 112.64 kbps (playback of recorded primary and secondary subframes of the PCM format) and 126.72 kbps (playback of recorded output from the data systems of experiments M509, T020 and T013.) The playback voice signal output will be an analog signal with a bandpass extending from 6.6 kHz to 66.0 kHz. Provisions will be incorporated in the AM to route any of the data from the data sources listed above to any one of the three ten-watt VHF FM transmitters or the two-watt transmitter and to activate or deactivate individually all of the four VHF FM transmitters. This switching may be controlled manually be a crewman in the AM through the control and display panel or by command from the MSFN via the up-data system of the AM.

2.1.2.4 Up-Data

The up-data receiving and decoding system of the AM will be capable of (a) detecting a 450 MHz carrier frequency modulated ($\pm$50 kHz peak frequency deviation) by a composite signal including a 2 kHz tone phase shift-keyed (PSK) by a serial bit stream of 1000 bits per second, linearly summed with a 1 kHz synchronization tone, (b) demodulating the PSK signal, (c) decoding the bit stream consisting of five sub-bit encoded information bits to derive the up-data information bits at a corresponding rate of 200 bits per second, and (d) routing the commands to the proper location for action. The up-data messages will consist of (a) real-time command functions which will operate (set or reset) relays, (b) up-date of an electric timer which will be used as part of the automatic redundancy control subsystem of the up-data system, and (c) messages for hard copy printout by the on-board teleprinter. Except for the case of teleprinter messages, the up-data decoding system will determine whether or not the received message was a valid command and will provide a signal to the telemetry system of the AM for transmission to the MSFN indicating reception of a valid up-data message when applicable. For the case of teleprinter messages, the validity of the vehicle address and the teleprinter system address (as well as the sub-bit encoding of the information bits) will be checked and the message will be rejected unless the decoded vehicle and teleprinter system addresses are both correct. There will be no indication sent to the MSFN that a valid teleprinter message has been received by the up-data system of the AM.

The up-data system will include redundant up-data receiver and decoder units, plus a command relay driver unit (CRDU), an automatic up-data receiver and decoder unit redundancy control subsystem, and a teleprinter subsystem.

2.1.2.4.1 Up-Data Receiver and Decoder Units

Each up-data receiver and decoder unit will include two receivers, a single decoder shared by the receivers and a 24-bit buffer storage unit. One receiver of each unit will be hardwired through a coax switch to one antenna of the AM antenna system and the second receiver of each unit will share another portion of the AM antenna system with the VHF FM transmitters of the AM through a quadriplexer. The audio outputs of the two receivers of each unit will be combined before being routed to the decoder of that unit. All receivers will operate at a nominal frequency of 450 MHz and have a minimum sensitivity of -93.0 dBm (intermediate frequency bandwidth of approximately 220 kHz and a noise figure of 18 dB). During prelaunch operations, a hardline on/off control of the AM up-data system will be provided to enable ground control of the AM up-data system. In addition, an umbilical connection through the coax switch mentioned above will be included to provide access by the ground to the radio frequency input of the AM up-data system for use during prelaunch checkout. A display will be provided to inform the crew when an up-data signal is being received by one or more of the four up-data receivers as determined by the automatic gain control levels of these four receivers.

The decoder, which is a decoder of the type used in the Gemini spacecraft, is provided with the capability of handling and routing 64 real-time commands (RTC's) corresponding to 32 set/reset command channels (32 latching relays) and with a stored program capability for insertion of stored program commands (SPC's) into the Gemini spacecraft computer. Since 32 real-time set/reset command channels will not be sufficient to fulfill the requirements identified for the AM up-data system, additional real-time set/reset command channels will be obtained by converting SPC messages into RTC's through use of the CRDU. The addition of the CRDU will provide the up-data system of the AM with the capability for supporting an additional 198 real-time set/reset command channels corresponding to 396 RTC's. The CRDU will contain two identical sets of a decoder plus relay drivers. Each set will be dedicated to a different one of the redundant up-data receiver and decoder units. The outputs of the two sets of relay drivers in the CRDU will be paralleled to their common destination of banks of latching relays using diode isolation. In a similar manner, except for one command channel from each up-data receiver and decoder unit which are used as inputs to the redundancy control unit, the outputs from the two up-data receiver and decoder units which operate relays directly without going through the CRDU, set countdown timers, or drive the teleprinter system will be paralleled to their common destinations using diode isolation.

Disregarding sub-bit encoding, each RTC will contain 12 bits composed of a 3-bit vehicle address followed by a 3-bit system address and a 6-bit command information word. Each SPC will contain 30 bits composed of the same 3-bit vehicle address followed by a different 3-bit system address and a 24-bit command information word. In addition to RTC's and SPC's, commands to set either one of two countdown timers (Section 2.1.2.4.2) can also be processed by the up-data receiver and decoder units. Commands to each of the two countdown timers will be composed of the same 3-bit vehicle address as used for RTC's and SPC's followed by different 3-bit system address and a 24-bit command information word. The decoder of either up-data receiver and decoder unit will provide a verification indication to the telemetry system of the AM for transfer to the MSFN upon receipt of a valid RTC, SPC, or timer set commands. Each sub-bit must be correctly received before an address or an information bit will be recognized as valid and all vehicle and system address bits and command information bits must be correctly received and decoded before any command message will be regarded as valid by the decoder or be acted upon. The CRDU will provide an output to the AM telemetry system for transfer to the MSFN indicating the specific relay command processed. Commands to drive the teleprinter system (Section 2.1.2.4.3) will include the same 3-bit vehicle address as used for RTC's and SPC's, a different 3-bit system address, and a 24-bit command information word. The up-data receiver and decoder unit will not provide an indication to the AM telemetry system that a valid teleprinter command has or has not been received.

After receipt of a valid vehicle address and a valid system address corresponding to either an SPC or timer set command, the following 24 decoded command information bits will be routed to and stored in the 24-bit buffer storage unit of the up-data receiver and decoder unit. After the buffer has been filled, ready pulses will be generated by the decoder of the up-data receiver and decoder unit to alert the CRDU or the appropriate input to the electronic timer that a command information word is waiting. The signalled CRDU or electronic timer will then send out 24 clock pulses to the decoder and the decoder will transfer the stored command information word bits serially to the CRDU or that electronic timer.

2.1.2.4.2 Up-Data Receiver and Decoder Unit Redundancy Control Subsystem

At any given time during the SL-1 mission, one of the two up-data receiver and decoder units will be operating and the other will be inactive. Selection of the unit to be active may be accomplished manually by a crewman from the AM control and display panel, by the MSFN via the up-data system of the AM, or automatically. In the automatic mode of operation, one of the redundant electronic timers will be used to activate the second up-data receiver and decoder unit unless the time-to-go-to-retro (T_r) input to the timer is periodically reset by the MSFN by update commands through the first unit. If the second unit is activated by the timer, the first up-data receiver and decoder unit may be deactivated manually by the crew or by command from the MSFN through the second unit. The electronic timer will be reset and will activate the first unit again after a given time period unless the T_r input to the timer is periodically reset by the MSFN by up-date commands through the second unit. This mode of operation and system design will require assignment of two vehicle addresses for AM up-data messages -- one for use when the first unit is active and the second for use when the second unit is active.

The redundant electronic timer will be provided as a backup to the primary electronic timer and will usually be inactive. The redundant timer can be activated manually be a crew member or by command from the MSFN after the primary timer has failed.

In addition to their use in the up-data receiver decoder unit redundancy control subsystem, the one of the redundant electronic timers which is active will provide a reading of elapsed time since activation serially to the AM telemetry system for transfer to the MSFN and to on-board experiments (M509, T013, and T020) and will provide an accurate countdown time-to-go-to-equipment-reset (T_x). The AM telemetry system will provide vehicle elapsed time words in the form of 24-bit word with a resolution of 0.125 seconds. Elapsed time kept by the AM telemetry system cannot be up-dated. The T_x input will or could be set through the up-data system of the AM during an MSFN station contact and after the AM passes out of line-of-sight of the station, the timer will countdown to zero and then provide a contact closure which will reset selected equipments to their normal state of operation during periods without MSFN station contact. This salvo reset capability is restricted to any number of the 32 latching relays which are controlled by RTC's. The relays which will be reset in this manner are not selectable after launch.

2.1.2.4.3 Teleprinter Subsystem

The teleprinter subsystem will include a teleprinter which will provide a hard copy printout of the up-data information and an interface electronics unit (IEU) which will provide the interface between the up-data receiver and decoder units and the teleprinter. The IEU will include decoder unit select/lockout circuitry, a system address detector, a 24-bit shift register, two 180-bit storage register, and a character generator.

Signals available at selected test points on each of the redundant up-data receiver and decoder units will be routed in parallel to the IEU through the decoder unit select/lockout circuitry. These signals include a vehicle address recognition pulse, a decoded bit sync signal, a decoded "0" bit signal, and a timing pulse 15 msec after the vehicle address recognition pulse has been generated in the up-data receiver and decoder unit. An output signal will be present at the decoded "0" bit test point only when a binary zero up-data information bit has been sub-bit decoded by the up-data receiver and decoder unit. A decoded "1" bit signal will be derived from the decoded "0" bit signal and the decoded bit sync signal. When data destined for hard copy printout in the OA is available on the ground, the data will be formulated into 30-bit (or 150 sub-bit) command words including a 3-bit vehicle address, a 3-bit system address, and a 24-bit information word. Upon receipt of a valid vehicle address, a vehicle address recognition pulse generated in either AM up-data receiver and decoder unit will be routed to the IEU where it will enable the system address detector in the IEU and will inhibit signals from the other up-data receiver and decoder unit from entering the IEU.

The next 3-bits as sub-bits decoded in the AM up-data receiver and decoder unit will be routed to the system address detector in the IEU as described above using the "0" bit and bit sync signals where the derived bits will be temporarily stored. Upon receipt of the 15 msec time delay pulse, the system address detector in the IEU will examine the 3 bits in temporary storage to determine if they correspond to the teleprinter subsystem address. If these do not correspond to the teleprinter subsystem address, the system address detector will be deactivated until another vehicle address recognition pulse is generated. If the teleprinter subsystem address is present, the next 24 information bits as sub-bit decoded by the AM up-data receiver and decoder will be routed and stored in the 24-bit shift register in the IEU. If less than 24 information bits are received and stored from any command word, the contents of the 24-bit shift register will be rejected and dumped. If 24 information bits were received and stored, the contents of the 24-bit register will be placed into one of the two 180-bit storage registers and a signal will be routed to the AM telemetry system for transmission to the MSFN indicating only that 24 information bits from one command word have been received and stored.

Six (6) information bits are required to define the specific alphanumeric symbol or character to be printed according to the 6-bit USA Standard Code for Information Interchange (USASCII). It is planned that one grouping of six information bits will be designated as a "print" command. Circuitry will be provided and located in front of the first 180-bit storage register to search the 24 bits routed from the 24-bit shift register to this 180-bit register in groups of 6-bits for the "print" command. Upon receipt of the "print" command or when the first 180-bit register has been completely filled, the contents of this register will be shifted into the second 180-bit storage register. Then the character generator using a 6-bit code to determine which 30 (or less) alphanumeric symbols are specified by the 180 (or less) bits in this second storage register will generate dot-row printing information using a 5x7 matrix for use by the teleprinter to form alphanumeric symbols or characters (a "space" is one of the possible characters). The contents of the storage register corresponds to one full line of alphanumeric symbols printed as hard copy by the teleprinter. While the contents of the storage register are being used for printing, subsequent command data bits decoded by the IEU after reception of another set of valid vehicle and teleprinter address patterns will be stored in the 180-bit shift register of the IEU.

The teleprinter will produce hard copy printout using a dot-row printing technique. There will be 150 dots per row which will allow 30 characters to be printed per line composed of seven rows. The teleprinter will print on thermally sensitive paper and will be capable of printing for 30 consecutive minutes but then must be deactivated for 15 minutes for cooling purposes. A crewman will be required to reload the paper cartridge with a fresh roll of paper as the paper is used. A manual paper advance switch will be provided on the teleprinter to enable a crewman to advance the paper in the teleprinter after a message has been received.

2.1.2.5 Television

The television system of the SWS will be composed of a video distribution network which will provide the means for routing selected video signals from either the television system of the ATM or from a portable television camera operating in the SWS to the CSM for subsequent transmission to the MSFN via the S-band FM transmitter. This video distribution network will include: (a) preinstalled coaxial cables in the SWS, (b) television input stations which also provide prime power to support the portable television camera in the MDA, the lock of the AM, the crew habitability quarters in the OWS, the experiment work area of the OWS, and the forward dome of the OWS, and (c) a coaxial switch. One coaxial cable will be routed through the SWS to support all television input stations for the portable television camera. Power to the television input stations for camera operation will be supplied by the module (MDA, AM, or OWS) in which the station is located. A video and power distribution switch will be provided at each television input station to provide deadfacing of the television input station when not in use and to break the coax cable at the input station when in use so that the coax cable will appear as a continuous run to the station without any shunt cable length introduced at the television input station in use. Two coaxial cables will be routed from the ATM television system, one from each of the two video coax switches located in the ATM, to a video coax switch located in the MDA. The coax cable used to support the portable television camera input stations in the SWS will also be routed to this video coax switch located in the MDA. This MDA video coax switch will enable a crewman to select manually which one or none of the three sources of video signals will be connected to the CSM/MDA hardwire interface. Conditioning of the video signals from the ATM television system will be provided as required by circuitry included in this MDA video coax switch. The frequency response of this video distribution system will be essentially flat over the frequency range of 0 to 4 MHz.

2.1.2.6 Tracking

A VHF ranging transponder system will be provided on the SWS to enable the CSM to determine the range between the

SWS and the CSM during rendezvous. The VHF ranging transponder system of the SWS will include a range tone transfer assembly (RTTA) and a radio frequency subsystem which will include a 259.7 MHz amplitude modulation receiver, a 296.8 MHz amplitude modulation transmitter, a diplexer and an antenna. The output of the 259.7 MHz receiver will be routed to the RTTA.

2.1.2.6.1 Range Tone Transfer Assembly

The RTTA will have the capability to determine automatically whether the course tone (247 Hz) added to the mid tone (3.95 kHz), the mid tone, or the fine tone (31.6 kHz) has been received by the VHF receiver. If the mid tone or the coarse tone added (modulo-2) to the mid tone is detected by the RTTA, the detected signal will be routed directly to the VHF transmitter for transmission after some reshaping of the signal is provided by passing the signal through a 3.95 Hz low pass filter. If the fine tone is detected by the RTTA, a fine tone tracking phase lock loop of the RTTA will be used to regenerate the fine tone prior to routing it to the 296.8 MHz transmitter for transmission. The locally regenerated fine tone will be in phase coherence with the detected fine tone.

2.1.2.6.2 Radio Frequency Subsystem

The 259.7 MHz amplitude modulation receiver will have a noise figure of 6 dB and an intermediate frequency bandwidth of approximately 70 kHz. The 296.8 MHz amplitude modulation transmitter will have a modulated output power of five watts (approximately 50 per cent duty cycle). The transmitter will be keyed by infinitely clipped ranging tones. The 259.7 MHz receiver and the 296.8 MHz transmitter will share an antenna subsystem through use of a diplexer. The antenna subsystem will consist of a circularly polarized five-turn helix antenna element fixed-mounted on the ATM deployment assembly of the SWS. This antenna will provide a gain of approximately 9 dB with a half-power beamwidth of 55 degrees. Coverage will be provided in the general direction of the plus X axis of the SWS after the ATM has been deployed.

2.1.2.7 Antenna System

The AM will be provided with two VHF/UHF antenna subsystems in addition to the antenna subsystem which forms part of the VHF ranging transponder system: (a) launch antenna subsystem and (b) Earth orbit antenna subsystem. The launch antenna subsystem will provide the necessary coverage to permit telemetry and up-data communications between the MSFN and the AM during prelaunch, launch, and Earth orbital phases of the mission prior to jettison of the upper portion of the payload shroud and deployment of the antenna booms. The Earth orbit antenna system will provide the necessary coverage to permit telemetry and up-data communications between the MSFN and the AM during the Earth orbital phases of the mission.

The launch antenna subsystem will consist of two linearly polarized stub antennas located 90 degrees apart on the stationary portion of the payload shroud. One antenna will be used for telemetry transmission and both antennas will be used simultaneously for up-data reception. One of the two receivers of each of the redundant up-data receivers will be hardwired through a coax switch to one of these two stub antennas. This coax switch will only be operated during prelaunch checkout phases of the mission and will enable commands to be routed to the redundant up-data receivers via hardwire through an umbilical connection. After prelaunch activities have been concluded, this coax switch will be left in the position so that the redundant up-data receivers will be permanently connected to the one stub antenna of the launch antenna system.

The Earth orbit antenna subsystem will consist of two linearly polarized discone antennas, each deployed on a different non-retractable antenna boom forty feet in length and spaced approximately 90 degrees apart and the one antenna of the launch antenna subsystem which was used only for up-data reception. The Earth orbit antenna subsystem will be used for telemetry and voice dump transmission to and up-data reception from the MSFN. The three VHF FM transmitters and redundant UHF up-data receivers will be multiplexed and switched from one antenna of the launch antenna system to either discone antenna after deployment of the antenna booms. The discone antennas will be fed through a switch to permit discone antenna selection. All switching discussed above may be accomplished via coaxial switches manually by a crewman or by command from the MSFN via the up-data system.

2.1.3 Communications System of the Apollo Telescope Mount

2.1.3.1 General

The Apollo Telescope Mount (ATM) will be equipped with

(a) an independent instrumentation and telemetry system for the transfer of systems status, systems performance and experiment output data to the MSFN in real-time and delayed-time and to the SWS in real-time.

(b) an independent up-data receiving and decoding system to permit the MSFN to exercise real-time control of experiments and system functions and to perform checkout of experiments and systems, and

(c) a television system to permit visual monitoring by crewmen in the MDA of the optical experiments and to provide video signals suitable for transmission to the MSFN via the S-band FM transmitter of the CSM.

The communications system of the ATM will be inactive until sometime after the ATM has been repositioned and the solar array panels have been deployed. Command and control of the ATM will be possible through the up-data system of the ATM or via the ATM control and display panel located in the MDA. Crewman control of the ATM will be accomplished via operation of function switches on the ATM control and display panel or via the digital keyboard on the ATM control and display panel which provides the crewmen with access to the redundant digital computers of the ATM. It is intended that the command and control signals generated by operation of switches on the MDA located panel will be limited to those that control crew safety subsystem functions, involve the crew as part of a proportional control loop, switch control panel meter readings or have high usage rates. The switches will operate switch selectors in the ATM which in turn will control specific operations of ATM systems. The command and control signals generated by manually punching the digital keyboard will be used to operate switch selectors in the ATM or to put data into the redundant ATM digital computers. A visual display will be provided in the MDA to enable the crewman to determine which keys were punched on the keyboard.

A number of the individual equipments comprising the communications system of the ATM will be an upgraded version of the variety used in the Saturn V and Saturn IB Launch Vehicles used in the Apollo Program. A block diagram of the communications system of the ATM described below is shown in Figure 2.3.1.

2.1.3.2 Instrumentation and Telemetry

The instrumentation and telemetry system of the ATM will include a measuring subsystem, multiplexer and PCM encoding subsystem, a tape recorder-reproducer subsystem, and a frequency transmission subsystem.

2.1.3.2.1 Measuring Subsystem

The measuring subsystem will consist of sensors, transducers, and signal conditioning equipment. The sensors and transducers will convert the quantity to be measured into an electrical signal. The signal conditioning equipment will condition the analog signals into the proper voltage range to be acceptable to the remote analog submultiplexers (-10 to +10 mVDC or 0 to +20 mVDC) and to the analog multiplexers (0 to +5 VDC). Signal conditioning racks (SCR's) will be provided at remote locations near the remote analog submultiplexers (RASM's) to condition analog signals prior to their input to the RASM. Each SCR will have the capability to condition 40 measurement signals. Individual signal conditioners will be co-located as required with those sensors or transducers whose outputs will be routed directly to the analog multiplexers.

All event and digital signals will be generated by their source as either 0 and ±5 VDC or 0 and +28 VDC signals. Consequently no conditioning of the event or digital signals will be required before they are routed to a remote digital multiplexer (RDM) or directly to the digital multiplexer in the PCM encoding subsystem.

2.1.3.2.2 Multiplexer and PCM Encoding Subsystem

The multiplexer and PCM encoding subsystem will include redundant Pulse Code Modulation/Digital Data Acquisition System (PCM/DDAS) assemblies or programmer-timing assemblies, four analog multiplexers or pulse amplitude modulation (PAM) time division multiplexer assemblies, and RASM's and RDM's which may be remotely located from the PCM/DDAS assemblies. Each PCM/DDAS assembly will include a PAM scanner, an analog-to-digital converter, digital multiplexing and formatting logic, clock and timing logic, a sync generator, a 600 kHz voltage controller oscillator, etc. The PCM/DDAS assembly will provide output signals for the radio frequency transmission subsystem, for the tape recorder-reproducer subsystem, and during pre-launch

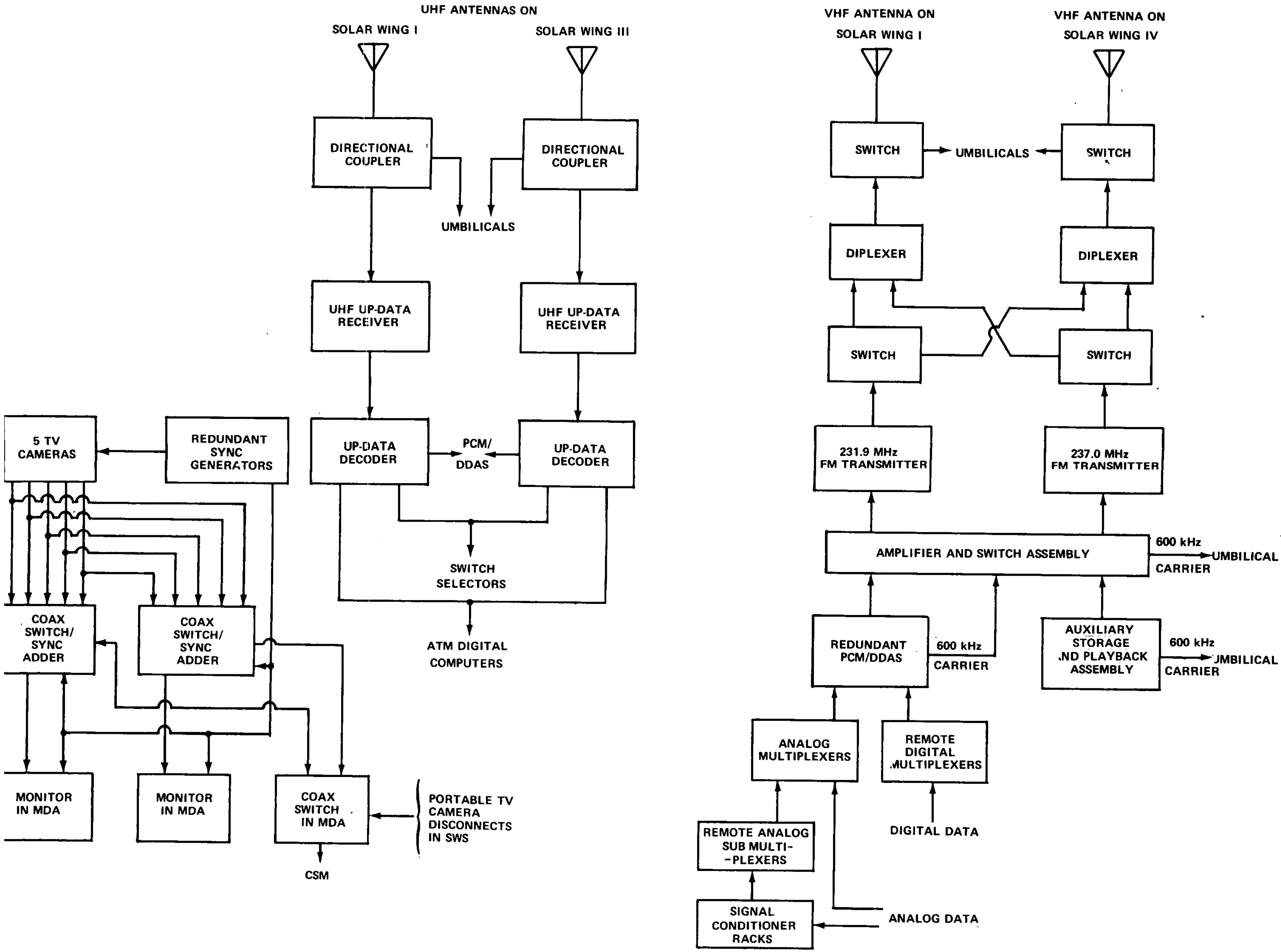

FIGURE 2.3.1 ATM COMMUNICATIONS SYSTEM

checkout for a hardline connection to the launch facilities. Only one of the two PCM/DDAS assemblies will be active at any given time as selected by a crewman in the MDA or by the MSFN via the ATM up-data system.

All of the multiplexers of this subsystem will be synchronized by the PCM/DDAS assembly. The outputs of the RASM's will be routed to the analog multiplexers and the outputs of the analog multiplexers and RDM's will be routed to the PCM/DDAS. Each RASM will have 60 channels, each analog multiplexer will have 270 channels, and each RDM will have the capability of accepting 100 bits of event and/or digital data and forming 10 channels of 10 bits. The inputs to the PCM/DDAS from the multiplexers and digital data directly from some sources will be encoded and combined with synchronization words into a programmed format which has been hardwired into the PCM/DDAS to form a PCM signal. The data cycle rate will be 4 times per second.

This PCM signal will be composed of words consisting of 10 bits which will be arranged with the most significant bit appearing first. The bi-level (on/off) channels will be grouped to form one word. Data in digital form with word lengths greater than 10 bits will be divided into 10 bit words which will be inserted in the PCM bit stream in different word time slots. The last three words (30 bits) in each frame will be used for synchronization and identification. This PCM signal will be provided in three different output forms: (a) a 72 kbps NRZ-L serial bit stream which will be routed to the radio frequency transmission subsystem for real-time transmission to the MSFN, (b) a 10-bit parallel output which will be routed to the tape recorder-reproducer subsystem for storage, and (c) a 600 kHz carrier frequency modulated by the 72 kbps NRZ-L PCM signal which will be routed via coaxial cable for connection to launch facilities. The PCM/DDAS assemblies will also provide sync pulses to the ATM experiments, star tracker, redundant digital computers. These three outputs and the sync pulses from both of the redundant PCM/DDAS assemblies will be routed first to the Amplifier and Switch Assembly (ASA) which will provide selection of the outputs from either the primary or the redundant PCM/DDAS assembly and will provide redundant line drivers for all ASA outputs except the 600 kHz modulated carrier which will only be switched by the ASA.

Redundant timers in the WCIU will provide mission elapsed time words in the form of 25-bit digital (BCD-binary coded decimal) words with a resolution of 0.25 seconds for inclusion in the

72 kbps NRZ-L PCM output from the PCM/DDAS assembly. The mission elapsed time kept by the timers in the WCIU can be updated by the MSFN via the ATM up-data system. If no up-dates are received, the mission elapsed time word will be recycled to zero every 64 days.

2.1.3.2.3 Tape Recorder-Reproducer Subsystem

The tape recorder-reproducer subsystem (or Auxilary Storage and Playback Assembly - ASAP) will accept the 10-bit parallel output from either of the redundant PCM/DDAS assemblies of the multiplexer and PCM encoder subsystem and will extract a total of 400 preselected 10-bit words of data and frame identification out of each 7200 words (four full cycles of the PCM programmer format) and will store the digital data at a rate of 4 kbps. Due to the restricted buffer capacity provided in the ASAP, there will be some limitation to which 400 words of the 7200 can be extracted. This limitation will be as follows: (a) any 100 words may be extracted from the first 1800 words, (b) any 100 words may be extracted from the second 1800 words, (c) any 100 words may be extracted from the third 1800 words, (d) any 100 words may be extracted from the fourth 1800 words, and (e) once the 400 word locations have been selected the same 400 words out of subsequent 7200 word blocks routed to the ASAP will be extracted.

The buffering capability provided in the ASAP assembly will provide the interface between the asynchronous extraction of words from the 10-bit parallel output from the multiplexer and PCM encoder subsystem and the readout of these words in a serial NRZ-L format with the most significant bit appearing first at a constant rate of 400 words per second or 4 kbps. The 4 kbps NRZ-L PCM signal and a 4 kbps clock signal will be routed to the tape recorders where the 4 kbps NRZ-L PCM signal will be converted into a split-phase (bi-phase-level) PCM bit stream of 4 kbps which can be stored by the tape recorders.

The ASAP assembly will include two tape recorders, one of which will be nominally redundant. However, the recorders may be operated to record simultaneously or sequentially and to playback sequentially as determined by a crewman in the MDA or by the MSFN via the up-data system of the ATM. Each recorder will be capable of recording split-phase PCM data at a rate of 4 kbps for a maximum continuous duration of 90 minutes. The redundant tape recorder may be used once per day on a contingency basis without significantly degrading the reliability of the overall tape recorder-reproducer subsystem for the ATM mission to provide continuous record times of up to 180 minutes. It is planned to operate both recorders during the launch phase of the ATM mission to avoid possible damage to the tape recorders.

Upon command by a crewman in the MDA or by the MSFN via the ATM up-data system, either recorder will play back the stored data at a rate 18 times faster (72 ips) than the record rate (4 ips). Since the recorders are pseudo-endless loop recorders, rewinding of the tape prior to playback is not required and the data stored first will be readout first. However, regardless of the number of minutes of data stored on either of these recorders, 5 minutes will be required to play back the stored data on each recorder because of the pseudo-endless loop feature of the recorder design. Approximately 3 seconds is required for the tape speed of the recorder to stabilize when the tape direction is reversed to form a square loop (pseudo - endless loop). The tape will be erased only during the record mode thereby providing the capability for a redump of the recorded data. The output of the playback electronics of each recorder will be a split-phase PCM signal at an apparent data rate of 72 kbps. The split-phase PCM signal output from either recorder will be selected in the ASA and will be routed through appropriate redundant line drivers in the ASA to the radio frequency telemetry transmission subsystem as determined by a crewman in the MDA or by the MSFN via the up-data system of the ATM. A six minute timer will be supplied in the ATM which will be initiated upon receipt of the recorder dump command. Unless a counter command is received, the recorder which was commanded to dump its stored data will play back the stored data for 6 minutes and will be returned to the record mode automatically by the timer.

The ASAP assembly will be provided with a 600 kHz voltage controlled oscillator (VCO). This 600 kHz carrier may be frequency modulated by either the 4 kbps NRZ-L PCM signal input to the tape recorders of the ASAP assembly or by the 72 kbps split-phase PCM signal output from either one of the tape recorders selected in the ASA. This modulated 600 kHz carrier will be routed via coaxial cable for connection to launch facilities during the prelaunch checkout of the ATM.

2.1.3.2.4 Radio Frequency Telemetry Transmission Subsystem

The radio frequency telemetry transmission subsystem of the ATM will include two FM telemetry transmitters, a number of coax switches and an antenna subsystem. The two FM telemetry transmitters will operate in the VHF telemetry frequency band (231.9 MHz and 237.0 MHz, respectively) and will be capable of simultaneous operation on a non-interference basis. Provisions will be included to enable a crewman in the MDA or the MSFN via the ATM up-data system to route either the real-time 72 kbps PCM signal or the split-phase PCM signal output from redundant recorders of the

ASAP selected in the ASA to either or both of the two FM telemetry transmitters. During periods when one of the redundant recorders is being dumped, the real-time PCM signal will be routed to one transmitter and the delayed-time PCM signal will be routed to the other transmitter. During periods when neither recorder is dumping data, the real-time PCM signal will be routed to both transmitters.

The antenna subsystem will include two linearly polarized antenna elements, a coax switch associated with each antenna element, and a diplexer associated with each antenna element. The antenna elements will operate in the 225 to 240 MHz frequency band. One of these antenna elements will be located near the end of one of the four ATM solar panels (wing I) and the second will be located near the end of an adjacent ATM solar panel (wing IV). The orientation of these antenna elements will be chosen such that the radiation converge pattern produced by each element will complement that produced by the other. The coax switch associated with each antenna element will be placed in the transmission line between the antenna element and the corresponding diplexer and will enable the RF output of the diplexer to be routed to the launch facilities via an umbilical during prelaunch checkout.

The RF output of each telemetry transmitter will be routed to a coax switch. These two coax switches will enable a crewman in the MDA or the MSFN via the ATM up-data system to route the RF output of either transmitter to the diplexer associated with either antenna element. The RF outputs of both transmitters need not be routed to the same diplexer and will normally not be when both transmitters are transmitting the same real-time 72 kbps NRZ-L PCM signal.

2.1.3.3 Up-Data

The up-data system of the ATM will be capable of receiving a UHF carrier (450 MHz) frequency modulated (± 50 kHz peak frequency deviation) by a composite baseband signal, detecting the composite signal, and decoding the detected signal to derive the up-data information. The composite signal will consist of a 1 kHz reference tone linearly summed with a 2 kHz tone which will be phase shift keyed at a 1 kHz rate by a digital signal of 1000 sub-bits per second (corresponding to an information bit rate of 200 bps where each bit is encoded into 5 sub-bits). The up-data system will include a UHF antenna subsystem and two UHF FM receivers and decoders.

The UHF antenna subsystem will consist of two linearly polarized dipole antenna elements,one located near the end of one of the four solar array panels (wing I) and the other located near the end of the diametrically opposed solar array panel (wing III). The UHF up-data signal received by each UHF antenna element will be routed to a different one of the redundant UHF up-data receivers through a directional coupler. The directional coupler will provide a means for connecting a test transmitter to the up-data receivers via coaxial cable umbilical connections during prelaunch checkout when the UHF up-data antenna subsystem will not be accessible.

The UHF FM receivers will operate at a nominal center frequency of 450 MHz, will have an IF bandwidth of 340 kHz, and will have a noise figure of 12 dB. The receivers will operate continuously and simultaneously. The audio output of each receiver will be routed to a different sub-bit detector and decoder. The sub-bit detector will recover the encoded up-data message at a rate of 1000 sub-bits per second. Each up-data message word will be composed of 35 information bits (or 175 sub-bits). The first 3 bits of the message will be the vehicle address,11 bits distributed among the remaining 32 bits will be the decoder address, and the remaining 21 bits will be the command. The decoder will search any received up-data message for a valid vehicle address sub-bit pattern and will then determine if the ATM vehicle address is present. If either the sub-bit pattern or the vehicle address are incorrect, the decoder will reject the up-data message. If the sub-bit pattern and the vehicle address are both correct, the ensuing sub-bit patterns will be decoded into bit information. If any of these sub-bit patterns are incorrect, the entire up-data message will be rejected. If the sub-bit patterns of the entire up-data message are correct, the remaining 32 bits of the up-data message will be routed to a 32-bit shift register in the decoder. After 32 bits have been loaded in the shift register, the decoder will check those bit positions in the storage register corresponding to the decoder address bit positions and will determine if a valid decoder address has been recieved. It should be noted that each of the two decoders of the ATM up-data system will be wired so as to respond to either of two decoder addresses, only one of which will be common to both decoders, thereby permitting the decoders to be used singly or in parallel. If the decoder address is found to be incorrect, the decoder will reject the up-data message.

If the decoder address is found to be valid, a verification signal (AVP) will be presented to the ATM instrumentation and telemetry system for transmission to the MSFN and the command information will be gated from the 32-bit shift register to the input of the proper equipment, either the redundant ATM digital computers through the WCIU or one of the four switch selectors (for execution of on/off or discrete commands). The destination of the command information is determined by the particular position out of five possible positions in the command information word of the "enable" bit. If more than one bit is present in the "enable" bit positions, the up-data message will be rejected by the decoder. It should be noted that the outputs of the separate decoders will be routed in parallel to their common destination using diode isolation. Finally, if a "one" is present in the "execute" position of the command word, the command routed to one of the five aforementioned locations will be executed, otherwise the command will be rejected.

A crewman in the MDA will be provided with the capability to inhibit all up-data messages to the ATM up-data system from the MSFN. It should be noted that the ATM up-data system will provide a backup to the on-board crew and that any function which may be commanded by the MSFN via the ATM up-data system including ATM digital computer up-dates can also be commanded by a crewman in the MDA via the ATM control and display panel. It should be noted that the up-data message transmission rate will be restricted to a maximum of three words of 175 sub-bits a piece per second by the ATM up-data system design. Each combination of UHF up-data receiver and decoder may be deactivated by command from the MSFN via the other combination of UHF up-data receiver and decoder.

2.1.3.4 Television

A television system will be provided in the ATM to enable crewmen in the MDA to monitor the field of view of the optics used for the various ATM solar experiments. The viedo displays provided to the crewmen will be used to aid in the pointing of the ATM optics and in the selection of scenes to be photographed. Additional provisions will be included to enable selected video signals present in the ATM closed circuit television system to be conditioned as required and routed to the CSM for transmission to the MSFN.

The closed circuit portion of the ATM television system will include 5 television cameras in the ATM and 2 television display monitors (7 inch cathode ray tubes) on the ATM control and display panel located in the MDA. A specific camera(s) will be associated with each of various solar observation experiments and each camera will be equipped with special filters or converters to enable each to be sensitive to the particular spectral wavelengths of the respective experiment(s) which it supports. Each camera will be provided with separate power supplies, amplifiers, and other associated electronics, but all will share the redundant sync generators. The active one of the redundant sync generators will provide horizontal and vertical drive signals to each television camera and both monitors for synchronization. The sync generators will be selectable by the crew from the ATM control and display panel in the MDA. Two video coax switches, one switch associated with each of the two monitors, located in the ATM may be operated by the crew from the ATM control and display panel to enable either monitor to display the output of anyone of the five cameras.

The ATM television system will include two different types of cameras, vidicon and low-light-level television cameras. The resolution provided by both types of television cameras will be approximately 600 lines horizontal at picture center and 360 lines vertical. The horizontal scan rate will be 15.75 kHz and the frame rate will be 30 frames per second with each frame composed of two interlaced fields (60 fields per second vertical scan rate) corresponding to 525 lines per frame. The vidicon television camera will reproduce ten shades of gray while the low-light-level television camera will reproduce eight shades of gray.

In addition to the closed circuit television features of the ATM television system, it will be possible for a crewman to select the video output from anyone of the 5 ATM television cameras to be made available for transmission to the MSFN via the CSM communications system. This selection will be accomplished via the video coax switches in the ATM which are used for the selection of the video signal to be displayed on each monitor of the ATM control and display panel in the MDA. The video signal output of the television camera chosen for display on each of the on-board monitors will be the video signals available for transmission to the MSFN via the S-band FM transmitter of the CSM.

As indicated above, the television cameras used in the closed circuit television system of the ATM provide standard commercial Electronic Industries Association (EIA) format video signal outputs with the exception of sync pulses. Synchronization pulses will not be included in these signals because the required horizontal and vertical drive signals for cameras and monitors will be provided by the redundant sync generators of the closed circuit television system. In order that the video signals from the ATM television system which will be transmitted to the MSFN will be compatible with commercial television receivers, sync pulses must be added to those video signals from the ATM television system made available for transmission to the MSFN. A sync adder will be included in each of the two video coax switches to provide the required sync pulses addition to those ATM video signals being made available for transmission to the MSFN. The function of the sync adder will be to derive sync pulses from the horizontal and vertical drive signal outputs from the redundant sync generators of the ATM television system and to add the derived sync pulses to the video signal output from the selected ATM television camera to form a composite signal which will meet the standards for black and white television signals contained in EIA Standard RS170. Separate coax cables will be routed from each of the two video coax switches of the ATM television system to the MDA video coax switch (Section 2.1.2.5) where the selection will be made as to which video signal will be routed to the CSM communications system for transmission to the MSFN. The ATM video signals will be conditioned by circuitry included in the MDA video coax switch to the proper bias and voltage levels for compatibility with the S-band FM transmitter of the CSM.

2.2 Mission SL-2

The communications systems of the various modules in mission SL-2 are described in the following sections as designated below:

(a) Saturn IB Launch Vehicle in Section 2.2.1,

(b) CSM in Section 2.2.2, and

(c) Crewmen in Section 2.2.3.

The radio frequency systems of the various modules in mission SL-2 are listed in Table 2.2.1

2.2.1 Communications System of the Saturn IB Launch Vehicle

2.2.1.1 General

The communications systems of the Saturn IB Launch Vehicle will provide the following functions:

(a) telemetry transmission to the MSFN,

(b) command-destruct data reception from the AFETR,

(c) up-data reception from the MSFN, and

(d) tracking aid to the MSFN and the AFETR.

Block diagrams of the communication system of the S-IB stage, the S-IVB stage, and the Instrument Unit described below are shown in Figures 2.2.1, 2.2.2, 2.2.3, respectively.

2.2.1.2 Instrumentation and Telemetry

Each stage of the Saturn IB Launch Vehicle (S-IB and S-IVB) and the Instrument Unit (IU) will be equipped with an independent measuring and telemetry system to minimize the number of stage interfaces. For efficient handling of the diversified data, two modulation techniques (PCM/FM and FM/FM will be used for RF telemetry transmissions to the MSFN. The instrumentation and telemetry systems of the Saturn IB Launch Vehicle will include measuring subsystems, FM/FM telemetry subsystems, PCM telemetry subsystems, and RF telemetry transmission subsystems.

TABLE 2.2.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-2

Location	System	Frequency (MHz) Transmit	Receive	Modulation
S-IB	Telemetry	240.2		FM/FM
	Telemetry	256.2		PCM/FM
	Command-Destruct		450	FSK/FM
S-IVB	Telemetry	258.5		PCM/FM
	Command-Destruct		450	FSK/FM
IU	Telemetry	250.7		FM/FM
	Telemetry	245.3		PCM/FM
	Up-Data		450	PSK/FM
	C-Band Transponder	5765.0	5690.0	Pulse
CSM	USB Transponder	2287.5	2106.4	PM
	S-Band Transmitter	2272.5		FM
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM
	Recovery Beacon	243.0		ICW

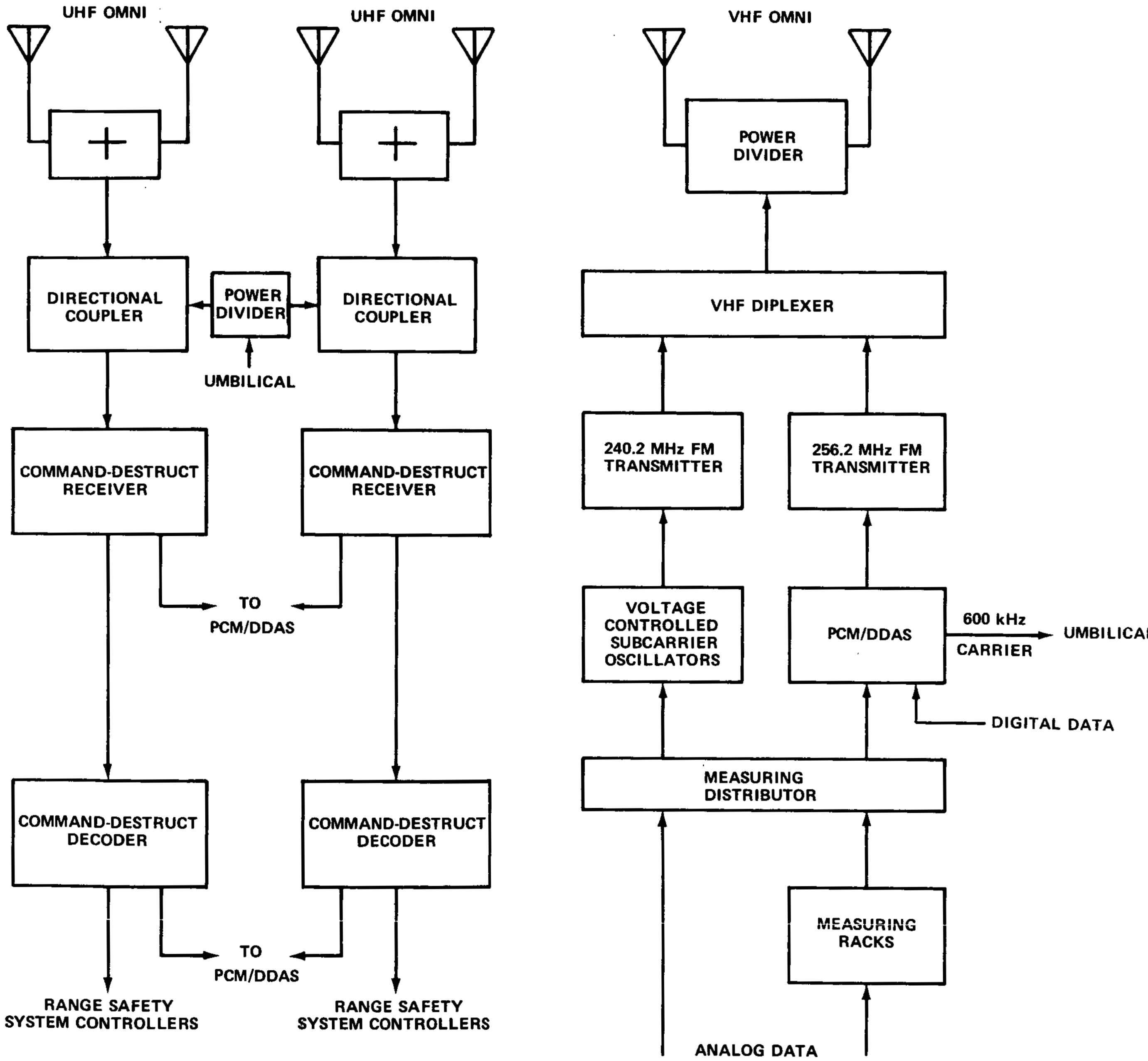

FIGURE 2.2.1 S-IB STAGE COMMUNICATIONS SYSTEM

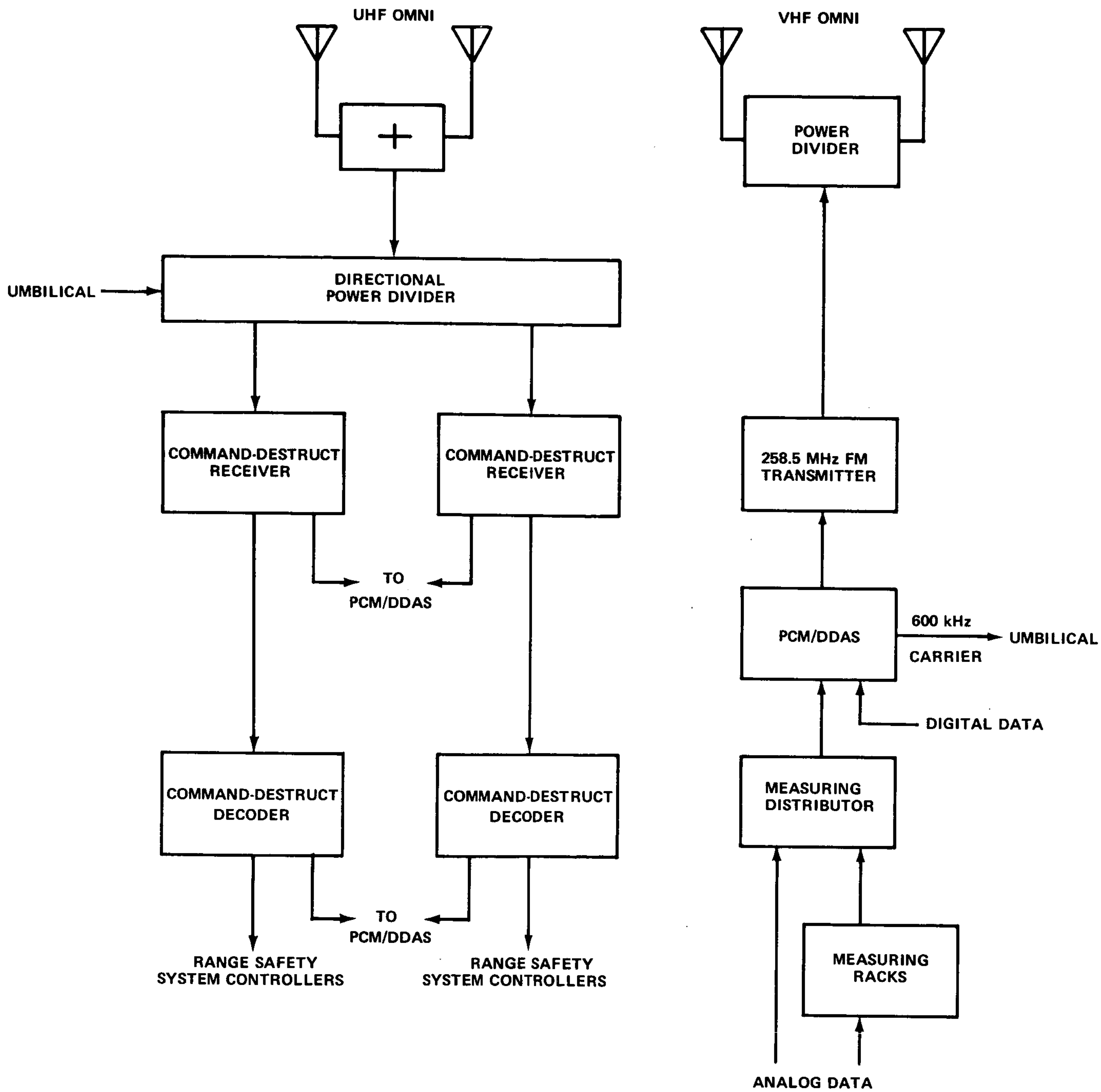

FIGURE 2.2.2 S-IVB STAGE COMMUNICATIONS SYSTEM

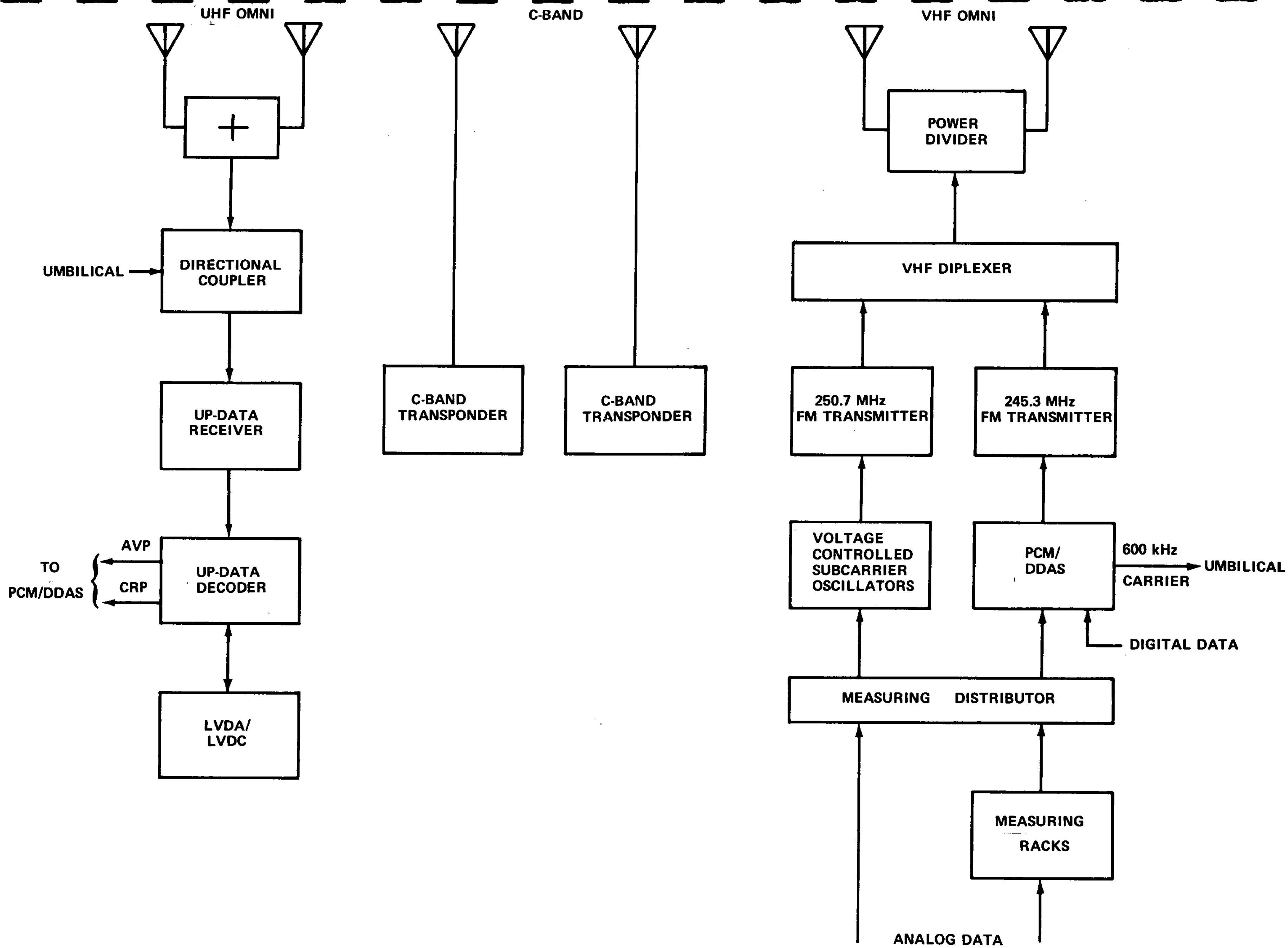

FIGURE 2.2.3 INSTRUMENT UNIT COMMUNICATIONS SYSTEM

2.2.1.2.1. Measuring Subsystem

The measuring subsystem of each stage and IU will consist of sensors, transducers, and signal conditioning equipment. This subsystem will convert the quantities to be measured into electrical signals and will condition the resulting signals to be acceptable to the FM/FM and PCM telemetry subsystems, as applicable. Since the measuring subsystems of the Saturn IB and Saturn V Launch Vehicles are basically the same, the reader is referred to Section 2.1.1.3.1 for a more detailed description of the hardware and operation of a measuring subsystem applicable to those of a Saturn IB Launch Vehicle.

2.2.1.2.2. FM/FM Telemetry Subsystems

The FM/FM telemetry subsystems of each stage and IU will be used for the transfer of data with bandwidths of up to 1 kHz and accuracies from 1 to 2 percent. These telemetry subsystems will conform to the Inter-Range Instrumentation Group (IRIG) Telemetry Standards for frequency division multiplexing (FM/FM) telemetry systems using proportional-bandwidth subcarrier channels. An analog signal will be routed from a measuring distributor of a stage to each voltage controlled subcarrier oscillator of the FM/FM telemetry subsystem of that stage and be used to frequency modulate that subcarrier oscillator frequency. The combined output of several subcarrier oscillators will in turn be used to frequency modulate an RF transmitter of the corresponding stage. The combined output of several subcarriers VCO's (up to 8) may also be used to frequency modulate another subcarrier VCO whose output will be included in the combined output of several subcarrier VCO's which will frequency modulate an RF transmitter. In this manner, up to the maximum required 27 continuous analog channels can be provided by each FM/FM telemetry subsystem.

2.2.1.2.3 PCM Telemetry Subsystems

The PCM telemetry subsystem of each stage and IU will be used for the transfer of sampled narrow bandwidth data with high accuracy, data originating in digital form, and the data on launch vehicle systems performance required on the Earth for checkout and/or flight control of the launch vehicle. Since the PCM telemetry subsystems of the Saturn IB and Saturn V Launch Vehicles are basically the same, the reader is referred to Section 2.1.1.3.3 for a more detailed description of the hardware and operations of a PCM telemetry subsystem applicable to those of a Saturn IB Launch Vehicle.

The 72 kbps NRZ-L wavetrain generated by each PCM telemetry subsystem will be composed of words consisting of ten bits which will be arranged with the most significant bit appearing first. Ten bi-level channels will be grouped to form one word. Data in digital form with word length larger than 10 bits will be divided into 10 bit words and will be inserted in the PCM wavetrain in different word time slots. The last three words in each frame will be used for synchronization and identification.

The digital data contained in the separate PCM wavetrains generated in the S-IVB stage and the IU will include all data required in real-time by the MSFN from both the S-IVB stage and the IU during coast in Earth parking orbit except for the bit stream from the launch vehicle digital computer which will appear only in the PCM wavetrain generated in the IU.

2.2.1.2.4 Radio Frequency Telemetry Transmission Subsystems

The S-IB stage and the IU of the Saturn IB Launch Vehicle will be equipped with two VHF FM telemetry transmitters operating in the 225 to 260 MHz frequency band, one for the transmission of the PCM wavetrain (PCM/FM link) and the second for the transmission frequency multiplexed data (FM/FM link). The S-IVB stage will be equipped with one VHF FM telemetry transmitter for the transmission of the PCM wavetrain. The output power of the VHF transmitters used for the PCM/FM telemetry links will be 15 watts and the output power of the transmitters used for the FM/FM telemetry links will be 20 watts.

The outputs of the PCM/FM and FM/FM telemetry transmitters of the S-IB stage will be multiplexed and will be fed simultaneously to two diametrically opposed linearly polarized antennas located on the S-IB stage operating in the 225 to 260 MHz frequency band and providing essentially omni-directional coverage.

The output of the PCM/FM telemetry transmitter of the S-IVB stage will be fed simultaneously to two diametrically opposed linearly polarized antennas located on the S-IVB stage operating in the 225 to 260 MHz frequency band and providing essentially omni-directional coverage.

The outputs of the PCM/FM and FM/FM telemetry transmitters of the IU will be multiplexed and will be fed simultaneously to two diametrically opposed linearly polarized antennas on the IU operating in the 225 to 260 MHz frequency band and providing essentially omni-directional coverage.

In addition to the VHF FM transmitters in each stage and IU used for transmission of the PCM wavetrains generated in the respective stage and IU, a 600 kHz carrier will be available in each PCM telemetry subsystem to enable transmission of the real-time PCM wavetrain from each stage and IU via coaxial cable to ground based checkout equipment during prelaunch activities. The 600 kHz carrier of each PCM telemetry subsystem will be frequency modulated by the 72 kbps NRZ-L PCM wavetrain generated by that subsystem.

2.2.1.3 Ground Command

2.2.1.3.1 Command-Destruct

Each powered stage (S-IB and S-IVB) of the Saturn IB Launch Vehicle will be provided with an independent command-destruct system to permit the Range Safety Officer to initiate emergency stage flight termination and propellant dispersion for range safety purposes. The command-destruct system of each powered stage will include two sets of identical, redundant command receivers and decoders which will be compatible with Range Safety Command transmitters installed at the stations of the AFETR. The signal which will be transmitted from the stations of the AFETR will be a carrier frequency of 450 MHz which has been frequency modulated (± 50 kHz deviation) by digital command data. The minimum sensitivity of the on-board receivers will be -93 dBm (an intermediate frequency bandwidth of 340 kHz and a noise figure of 12 dB).

Each of the two sets of identical, redundant command-destruct receivers and decoders located in the S-IB stage will be provided with a separate omni-directional antenna system operating in 400 to 450 MHz frequency range. Each of these antenna systems will consist of two linearly polarized antenna elements spaced 180 degrees apart.

The two sets of identical, redundant command-destruct receivers and decoders of the S-IVB stage will simultaneously share a common omni-directional antenna system located on the S-IVB stage operating in the 400 to 450 MHz frequency band. This omni-directional antenna system will consist of two elliptically polarized antenna elements space 180 degrees apart.

The capability to feed the redundant receivers of each stage with the signal via an umbilical connection will be provided for use during prelaunch activities.

Since the command format and command-destruct system operation will be the same for Saturn IB and Saturn V

Launch Vehicles, the reader is referred to Section 2.1.1.4.1 for these details.

The three commands associated with these systems will be (a) thrust termination and arming of the destruct exploding bridgewire, (b) firing of the destruct bridgewire for propellant dispersal, and (c) command-destruct system deactivated. The last command will be accepted only by the S-IVB stage and once accepted the command-destruct system can never be reactivated.

2.2.1.3.2 Up-Data

The up-data system will include one receiver and decoder operating at 450 MHz with a minimum sensitivity of -93 dBm (an intermediate frequency bandwidth of 340 kHz and a noise figure of 12 dB). The up-data receiver and decoder will be fed by two diametrically opposed linearly polarized antenna elements on the IU operating in the 400 to 450 MHz frequency band and providing essentially omni-directional coverage. The capability to feed the up-data receiver via an umbilical connection will be provided for use during prelaunch activities.

The receiver will be capable of demodulating a 450 MHz carrier which has been frequency modulated ($\pm$ 25 kHz peak deviation per tone) by an up-data composite signal consisting of a 1 kHz synchronization tone linearly combined with a 2 kHz tone which has been phase shift keyed by a serial bit stream of 1000 bps. The up-data composite signal will then be routed to the decoder for appropriate action. Since the up-data word format and the decoder operation are the same for the up-data systems of both the Saturn IB and Saturn V Launch Vehicles, the reader is referred to Section 2.1.1.4.2 for these details.

2.2.1.4 Tracking

The IU will be equipped with two C-band radar transponders with independent antennas. Both transponders will be active during the launch phase, but only one transponder will be active at any one time during the Earth orbital coast phase according to ground command or IU computer controlled pre-programmed schedule. Each transponder will be set to receive a single pulse at a carrier frequency of nominally 5690 MHz and will respond with a single transmitted pulse at a carrier frequency of nominally 5765 MHz. The output of the transponder transmitter will be a minimum of 400 watts peak power and the receiver will have a sensitivity of at least -65 dBm with a half-power intermediate frequency (IF) bandwidth of 10 MHz.

Each one of the two C-band transponders will be provided with a separate right hand circularly polarized antenna operating in the 5690 to 5765 MHz frequency band which will serve for both transmitting and receiving functions of that transponder. The two antennas will be located on the IU and be spaced 180 degrees apart and will separately provide essentially hemispherical coverage.

2.2.2 Communications System of the Command and Service Module

2.2.2.1 General

The CSM will be equipped with a voice communications system, an instrumentation and telemetry system, an up-data system, a tracking system, and a television system. These systems are described in the following sections. These systems will use the Unified S-Band (USB) communications system and VHF transmitters and receivers which are described below for extending communications external to the CSM structure. In addition to these systems, VHF recovery communications systems will be carried by the CM for use after reentry into the Earth's atmosphere has been accomplished. All of these systems will be carried by the Block II CSM's of the Apollo Program; however, some slight modification to most of these systems will be required for the Skylab Program. The recovery communications systems will not be discussed further in this memorandum. A block diagram of the communications system of the CSM described below is shown in Figure 2.2.4.

The premodulation processor (PMP) and the communications controls on the CSM control and display panels form the heart of the CSM internal communications distribution and control system. The PMP will provide the interface between the Unified S-Band equipment and the on-board data gathering and distribution equipment and will accomplish signal modulation, demodulation, mixing, switching, and routing to enable proper operation of all required communications modes of the USB communication links. Inputs to the PMP will include signal outputs from the television equipment, the PCM telemetry equipment, the central timing equipment, the USB equipment (30 kHz and 70 kHz subcarriers modulated), audio center equipment, and voice and data storage equipment. Signals processed within the PMP will be routed as required to the audio center, voice and data storage equipment, up-data decoding equipment, and USB equipment (modulated 1.024 MHz and 1.25 MHz subcarriers, television, back-up voice, etc.).

The communications controls will provide the crew members with the capability to control the operation of the CSM communications systems, including selection of the mode of operation of the USB and VHF equipments; selection of redundant equipment to be used; routing of voice, telemetry and other signals through the PMP; and selection of the antenna to be used by any receiver or transmitter.

The primary communications link between the CSM and the MSFN will be via the USB communications system. MSFN to CSM communications via the S-band communications link will include a carrier plus, in various combinations, voice, up-data, and pseudo-noise range code. CSM to MSFN transmissions

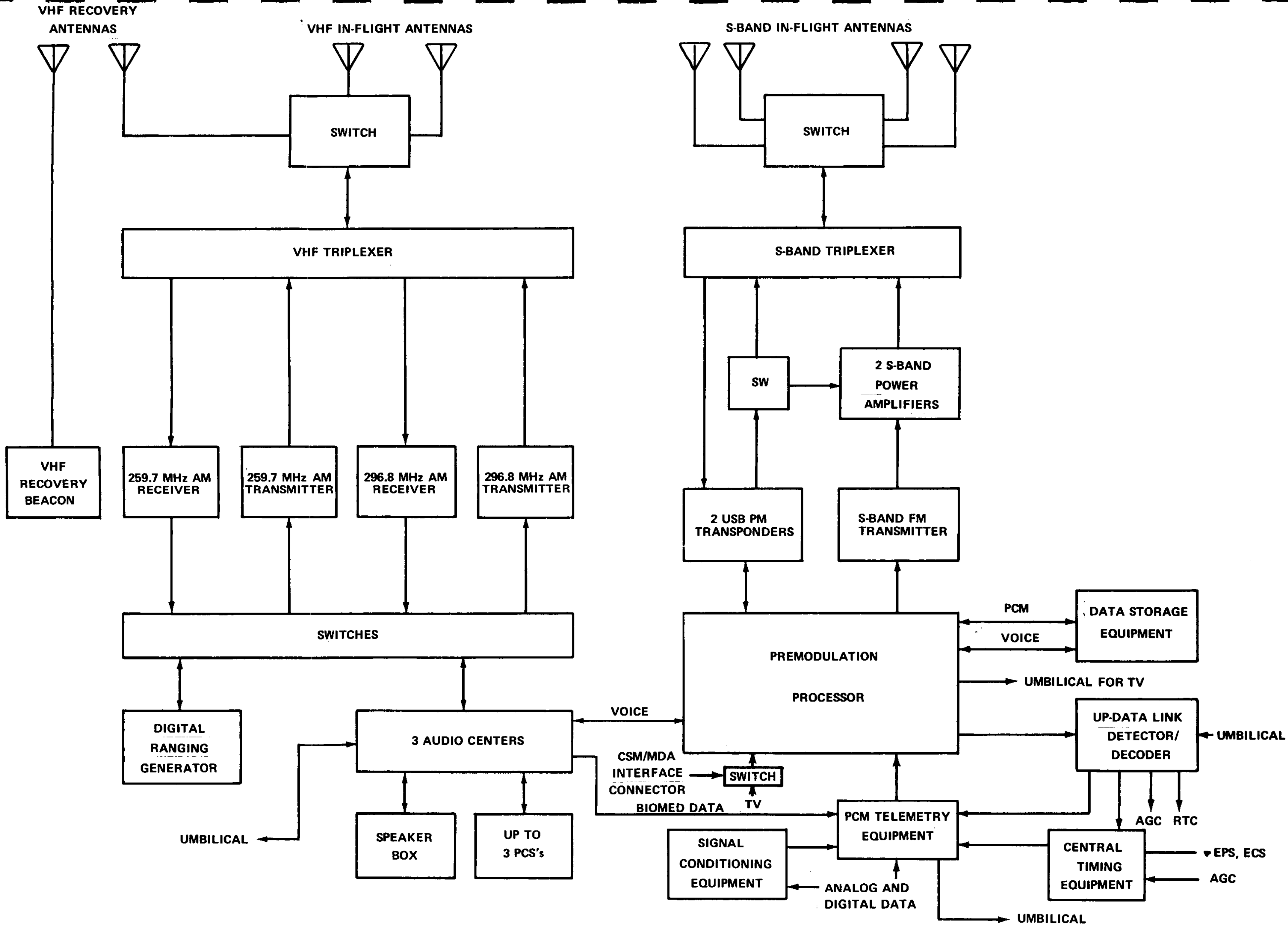

FIGURE 2.2.4 CSM COMMUNICATIONS SYSTEM

via the S-band link will include, in various combinations, voice playback of recorded voice, telemetry, playback of recorded telemetry, television , turn-around of pseudo-noise range code transmitted by the MSFN, and a carrier coherent with the carrier transmitted by the MSFN.

The VHF communications equipment will provide direct voice communications between the CSM and the MSFN and range tracking of a remote transponder located on the SWS.

2.2.2.1.1 Unified S-Band Communications System

The USB communications system of the CSM will include redundant PM transponders, one FM transmitter, redundant power amplifiers, a triplexer, and an antenna subsystem including four antenna elements. Various combinations of PM transponders, FM transmitter, power amplifiers, and antenna elements will be manually selectable from the CSM control and display panels by a crew member in accordance with the following constraints:

(a) Simultaneous operation of both PM transponders will be precluded.

(b) The FM transmitter and both PM transponders will be switchable to either power amplifier, but simultaneous use of the same power amplifier by a PM transponder and the FM transmitter will be precluded.

(c) The power amplifier associated with the FM transmitter will be automatically energized whenever the FM transmitter is activated.

(d) Bypass of either or both power amplifiers by a transmitted S-band signal from either of the PM transponders will be possible.

(e) Simultaneous use of more than one S-band antenna element will be precluded. (The RF input and output of either PM transponder and the RF output of the FM transmitter will be frequency multiplexed.)

2.2.2.1.1.1 Transponders

Each PM transponder will include a receiver, an auxiliary oscillator, a phase modulator, a multiplier chain, a power supply, and associated equipment. Either PM transponder will be capable of receiving and detecting a sufficiently strong component of the carrier frequency transmitted by the MSFN (nominally at 2106.4 MHz) and detecting a composite signal phase modulating the received carrier. The composite signal could include a pseudo-noise range code, a 30 kHz subcarrier frequency modulated by voice information, and a 70 kHz subcarrier frequency modulated by an up-data composite signal (or by voice information in a backup mode). The modulated subcarriers will be routed to the PMP for demodulation and the detected pseudo-noise code will be routed directly to the transmitter portion of the PM transponder for immediate transmission. The noise figure of the receiver of the PM transponder will be approximately 13.5 dB.

Either PM transponder will be capable of transmitting a carrier in phase coherence with the received carrier, but offset in frequency from the received carrier at a constant 240 to 221 frequency translation ratio, resulting in a transmitted carrier frequency of 2287.5 MHz. Each transponder will contain an auxiliary crystal-controlled oscillator to provide a carrier frequency (approximately 2287.5 MHz) in the event of a loss of received carrier. Selection of the auxiliary oscillator to provide a stalbe carrier will be done automatically within the transponder when received carrier is lost. The phase-modulator (modulation bandwidth: 300 Hz to 1.5 MHz) of each transponder will be capable of phase modulating the transponder transmitted carrier with a composite signal consisted of the pseudo-noise range code detected by the transponder receiver and/or a composite signal routed from the PMP. The output power of either transponder will be 250 milliwatts.

2.2.2.1.1.2 FM Transmitter

The FM transmitter will include a frequency-modulator and crystal-controlled oscillator and a multiplier chain to produce a transmitted carrier frequency of approximately 2272.5 MHz. The frequency-modulator (modulation bandwidth: dc to approximately 2.0 MHz) will be capable of modulating the carrier with a composite signal routed from the PMP. The output power of the FM transmitter will be 250 milliwatts.

2.2.2.1.1.3 Power Amplifiers

Each of the redundant S-band power amplifiers will include a traveling wave tube (TWT) for amplification and will provide two selectable output powers for signals in the 2270 to 2290 MHz frequency band. The output powers as measured at the output of the triplexer will be a minimum of 11.2 watts and 2.8 watts, respectively. The high-power mode will automatically be selected for the power amplifier connected to the FM transmitter. The power mode of operation (high-power, low-power, or bypass) of the power amplifier connected to either PM transponder will be selectable by the crew or the MSFN via the up-data system of the CSM.

2.2.2.1.1.4 Triplexer

A triplexer will provide the interface between the S-band antenna elements and the PM transponders and power amplifiers. A received S-band signal will pass through the triplexer directly to the transponder receiver. The transmitted signal from the transponder will be routed directly to the triplexer or through one of the power amplifiers to the triplexer. The transmitted signal from the FM transmitter will be routed through the second power amplifier to the triplexer.

2.2.2.1.1.5 S-Band Antenna System

The omni-directional S-band antenna system will consist of four flush-mounted, right-hand circularly polarized antenna elements located on the CM and spaced 90 degrees apart. Radiation will be possible from only one of the elements at any given time. The S-band antenna system will be shared by the USB PM transponder and FM transmitter through use of the triplexer. The capability will be provided to select the particular S-band antenna element to be used manually by a crew member from the communications control panel or remotely by the MSFN via the up-data link of the AM or via the up-data link of the CSM.

2.2.2.1.1.6 Modes of Operation of Unified S-Band System

The crew members will be capable of manually selecting the modes of operation of the USB system remotely from the communications control panel. Simultaneous transmissions from one PM transponder and the FM transmitter will be possible.

2.2.2.1.1.6.1 Receive Modes

The CSM will be capable of detecting a sufficiently strong component of the received carrier from the MSFN in all receive modes. In addition, the CSM will be capable of detecting a pseudo-noise range code, voice, and digital up-data in the following combinations:

(a) Range code, voice, and up-data.

(b) Range code and voice.

(c) Range code and up-data.

(d) Voice and up-data.

(e) Range code.

(f) Voice.

(g) Up-data.

The pseudo-noise range code will phase modulate the main carrier directly, the voice information will frequency modulate a 30 kHz subcarrier which will phase modulate the main carrier directly and the up-data message will frequency modulate a 70 kHz subcarrier which will phase modulate the main carrier directly. In a backup mode, the voice information will modulate the 70 kHz subcarrier.

2.2.2.1.1.6.2 Transmit Modes

The CSM will be capable of the following transmission modes of operation of each PM transponder:

(a) Voice and high bit rate PCM telemetry.

(b) Voice and low bit rate PCM telemetry.

(c) Voice, high bit rate PCM telemetry, and turn-around range code.

(d) Voice, low bit rate PCM telemetry, and turn-around range code.

(e) high or low bit rate PCM telemetry.

(f) Range code.

(g) Range code and low bit rate telemetry.

(h) Range code and voice.

(i) Voice.

The pseudo-noise range code will phase modulate the main carrier directly, the high (or low) bit rate telemetry signal will frequency modulate a 1.024 MHz subcarrier which will phase modulate the main carrier directly, and the voice information will frequency modulate a 1.25 MHz subcarrier which will phase modulate the main carrier directly.

In addition to the above normal modes of operation, the USB system of the CSM will be capable of transmitting voice information phase modulated directly on the main carrier with or without high (or low) bit rate telemetry frequency modulated on a 1.024 MHz subcarrier. The USB system will also be capable of transmitting a 512 kHz subcarrier which may be keyed by a crewman phase modulated directly on the main carrier.

The transmit modes of operation of the PM transponders described above will be selectable under crew control via switches on the communications control panel. In addition, the capability for transmission of turn-around range code can be added or subtracted as appropriate to any of these modes (thereby changing the transmission mode) by command from the MSFN via the up-data system of the CSM.

The CSM will be capable of the following transmission modes of operation of the FM transmitter simultaneously with PM transponder transmission:

(a) Television.

(b) Playback of recorded voice and playback of recorded CSM low bit rate telemetry or playback of either one at 32:1.

(c) Playback of recorded voice and playback of recorded CSM high bit rate telemetry at 1:1.

(d) Real-time high or low bit rate telemetry.

When transmitted, the television signal or the recorded voice playback signal will frequency modulate the main carrier directly and the real-time or recorded playback of high or low bit rate telemetry signal will phase modulate a 1.024 MHz subcarrier which will frequency modulate the main carrier directly.

The transmit modes of operation of the FM transmitter described above will be selectable under crew control via switches on the communications control panel or by the MSFN via the up-data system of the CSM.

2.2.2.1.2 VHF Transmitters and Receivers

The CSM will be equipped with one amplitude modulation transmitter and one amplitude modulation receiver operating at a nominal frequency of 259.7 MHz. These equipments may be operated in either a simplex or duplex mode as selected remotely by crew members from the communications control panel. Physical safeguards will be incorporated to preclude simultaneous operation of transmitter and receiver at the same frequency.

The two VHF transmitters will each have a modulated output power of five watts (approximately 50 per cent duty cycle). The transmitters will be 100 per cent modulated by infinitely clipped speech waveforms or ranging tones. The two VHF amplitude modulation receivers will have noise figures of 6 dB and an intermediate frequency bandwidth of approximately 70 kHz.

The 259.7 MHz and 296.8 MHz transmitters and receivers will share an inflight VHF antenna subsystem through use of a triplexer. The inflight VHF antenna subsystem of the CSM will be a linearly polarized omni-directional antenna subsystem operating in the frequency band of 250 to 300 MHz which will include two scimitar antennas located approximately 180 degrees apart on the outer skin of the SM. Only one of these antenna elements will be used at any given time. A manual switching capability will be provided to the crew members at the communications control panel to enable switching of the input/output of the triplexer from one antenna element to the other by operating a remotely located coaxial switch.

2.2.2.2 Voice Communications

Audio centers will be provided in the CSM to serve as the interface between the PCS of each crewman and (a) the PCS's of other crewmen via the intercom bus (b) the USB communications system and the VHF transmitters and receivers (VHF communications system) of the CSM and (c) the tape recorder-reproducer subsystem of the CSM.

There will be three identical electrical audio centers installed in the CM -- one for each crewman; namely, the Commander (CDR), the Command Module Pilot (CMP), and the Lunar Module Pilot (LMP). Each audio center will be capable of accommodating a second crew member in case of failure of one of the audio centers. Through appropriate switch selection, a crewman whose PCS is connected to the CDR audio center or to the LMP audio center can share the CMP audio center and a crewman whose PCS is connected to the CMP audio center can share the CDR audio center. It should be noted that the headset, microphone, and push-to-talk switch functions will be made available to both crewmen when one audio center is shared by two crewmen. The intercom bus, the pad communications bus, and the USB and VHF communications systems of the CSM will be common to the three audio centers. Hardline voice communications external to the CM will be provided for use during the prelaunch and recovery mission phases of the CM via the pad communications bus and the intercom bus, respectively. Each audio center will provide isolation, switching, and amplification of all audio signals independent of the other audio centers. The switching capabilities of each audio center will enable each crewman to control the routing of voice signals from the VHF communications system, the USB communications system (via the PMP), the intercom bus, the tape recorder-reproducer system, the pad communications bus, and/or his PCS as required to the VHF communications system, the USB communications system (via the PMP), the intercom bus, the pad communications bus, and/or his PCS.

Each audio center will enable each crew member to select and to monitor individually or in combination voice signals from the pad communications bus, the VHF and USB communications systems, and the intercom bus. A control will be provided which when activated will inhibit transfer of audio signals to the PCS of a crewman, but will pass an alarm tone from the caution and warning system. Individual level controls will be provided at each audio center to permit each crew member to control the volume of voice signals received by his headset. The 3 dB frequency response will be 300 to 3000 Hz.

Each audio center will be provided with a voice operated transmission switch (VOX), including a thumbwheel sensitivity control, to permit the crew member to key the selected transmitter and/or intercom bus automatically with his voice. Each crew member will be provided with a push-to-talk (PTT) switch to permit manual keying of the selected transmitter and/or intercom bus for voice transmission. A "hot mike" capability will also be provided for direct connection of the microphone to the intercom bus. Sidetone will be provided in all transmit modes. Each audio center will include automatic volume control (AVC) of the voice signals from the microphone of the crewman's PCS (for a 20 dB increase in input level above threshold, the increase in output of the AVC circuit will not exceed 4 dB).

A fixed speaker and microphone (speaker box) will be provided in the CM for use with the CMP audio center to serve in lieu of the PCS to provide the voice communications capabilities to a crewman in the CM. A switch will be provided on the speaker box to enable a crewman to choose whether his PCS or the speaker box will be connected to the CMP audio center. A speaker volume control will be provided on the speaker box. The mode of operation of the speaker box may be selected by a crewman via a three-position switch as follows:

(a) Sleep (Power will be removed from the speaker box and speaker will be disconnected from the intercom bus.)

(b) On (Power will be provided to the speaker box and the speaker and microphone may be used to provide simplex communications.)

(c) Call (Power will be provided to the speaker box; a contact closure will be provided to the SWS which will result in the headset lines of the redundant hardlines being cross-connected in the AM and the activation of the warning alarm tone of the CWS of the SWS; and the microphone will be connected to the intercom bus through the CMP audio center.)

A second three-position switch will be provided on the speaker box to enable the crewman to select the mode of operation of the speaker and microphone when the speaker box mode switch is in the "ON" position described above. This switch will allow the crewman to operate the fixed speaker and microphone in a PTT mode (connects the microphone to the intercom bus and disconnects the speaker), a listen mode (connects the speaker to the intercom bus), or a PTX mode (connects the microphone to the intercom bus, disconnects the speaker, and enables the RF transmitter(s) previously selected on the CMP audio center in the CSM for voice transmission to the MSFN).

A panel will be provided in the CM which will be compatible with the EVA/IVA umbilical of the spacesuit of a crewman performing IVA using consumables from the CSM. This panel will be called an IVA panel. Oxygen and power for the spacesuit will be provided at the connector of the IVA panel which is compatible with the EVA/IVA umbilical. The IVA panel will also serve as a patch panel which will make accessible via a second connector the microphone lines, headset lines, biomedical data lines, and PTT circuitry lines from the spacesuit via the EVA/IVA umbilical. This second connector will be compatible with the crewman's communications umbilical (CCU). The CCU which normally provides the connection between the T-adapter of the crewman's PCS and an audio center of the CM will be used to provide the connection of the microphone, headset, biomedical data, and PTX circuitry lines from the IVA panel to an audio center of the CM.

Voice signals routed to the audio center and the PMP will be processed by peak clipping and pre-emphasis prior to routing to the VHF transmitter or USB system or the tape recorder-reproducer system. The voice signals will undergo +6 dB per octave pre-emphasis and 12 dB of peak clipping prior to being recorded or prior to transmission via the USB system in a normal mode, will undergo +6 dB per octave pre-emphasis and 24 dB of peak clipping prior to transmission via the USB system operating in a backup voice mode, and will undergo +6 dB per octave per-emphasis and infinite peak clipping prior to transmission via the VHF communications system.

One selectable mode of operation of the audio center, PMP and USB equipment will permit the push-to-talk switches to control manually keyed transmission of a 512 kHz subcarrier to the MSFN via the S-band PM communications link.

2.2.2.3 Instrumentation and Telemetry

The CSM will be provided with an independent measuring and telemetry system. Data outputs from sensors located in the CSM will be conditioned as required to conform to prescribed peak voltages for digital signals and voltage ranges for analog signals prior to presentation of the signals to the CSM PCM encoder subsystem, the CSM caution and warning system (CWS), and control panel displays. Some signals will be conditioned at the sensor output by individual conditioners while other signals will be routed to the centrally located signal conditioning equipment (SCE) for conditioning. Biomedical data from each crewman (electrocardiogram, heart rate, impedance pneumograph, body temperature, and subject identification) will be hardlined into the CSM telemetry system from his PCS through the respective audio centers. The biomedical data from up to three crewmen may be transmitted simultaneously. Data from on-board CSM experiments will also be routed to the PCM encoder subsystem.

The telemetry system of the CSM will include a PCM encoder subsystem and tape recorder-reproducer subsystem. All telemetry transmissions, both real-time and recorder dump, from the CSM will be accomplished via the USB system. The real-time PCM telemetry signal and the recorder dump PCM telemetry signal will be routed to the PMP. The tape recorder-reproducer subsystem will also be used for recording voice communications for delayed playback and transmission to the MSFN via the USB system.

2.2.2.3.1 Pulse Code Modulation Encoder Subsystem

The PCM encoder subsystem will be capable of processing and time multiplexing biomedical data, various spacecraft systems performance and status measurements, and experiment data in the form of high-level analog, low-level analog, parallel digital, and serial digital signals into (a) a serial, binary-coded, non-return-to-zero, digital signal where a "one" is represented by one level and a "zero" is represented by another (NRZ-L) and (b) a serial, binary-coded, return-to-zero, digital signal (RZ). The NRZ-L and the RZ PCM signals will contain identical data. The NRZ-L PCM signal will be routed in parallel to the PMP and to the tape recorder-reproducer subsystem. The RZ siganl will be routed via hardline to ground support equipment (GSE) during prelaunch checkout. The PCM signal will be composed of words or groups consisting of eight bits, the most significant bit appearing first. A 32-bit synchronization and identification code group will be included in every prime frame.

The redundant programmers of the PCM telemetry equipment will sample all or portions of the system performance and status measurement signals in accordance with one of the two built-in sampling programs that may be selected by a crew member of the CSM by remote control switches on the communications control panel or by the MSFN via the up-data system of the CSM.

The two programs provide a 1.6 kbps PCM data rate and a 51.2 kbps PCM data rate. The data cycle rate will be once per second in both modes.

The central timing equipment (CTE) which will be completely redundant will be the basic clock for all systems of the CSM and will provide the primary timing for the PCM telemetry equipment of the CSM as well as sequencing, synchronization and timing signals to other CSM systems. However, in the absence of an external timing signal, the PCM telemetry equipment will automatically switch and operate from its own internally generated timing signal. The CTE will be very stable because it will be phase locked to the temperature controlled crystal oscillator of the Apollo Guidance Computer. A time accumulator will be provided in the CTE and a 25-bit parallel binary-coded decimal (BCD) time code output from the time accumulator will be included in both the high and low bit rate PCM outputs from the PCM telemetry equipment for post-flight data time correlation purposes. The capacity of the time accumulator in the CTE will be approximately 20 days with a resolution of 1 second. The time accumulator may be up-dated or reset manually or remotely via the up-data system of the CSM.

2.2.2.3.2 Tape Recorder-Reproducer Subsystem

The tape recorder-reproducer subsystem (or Data Storage Equipment - DSE) of the CSM will be capable of recording simultaneously: (a) voice signals present on the intercom bus and (b) CSM NRZ-L PCM telemetry at either high or low bit rate correlated with a timing signal. The recorder playback electronics will permit: (a) parallel playback of voice and CSM high bit rate NRZ-L PCM telemetry at the record speed and (b) parallel playback of voice and CSM low bit rate NRZ-L PCM telemetry at 32 times faster than the record speed. The playback speed of the tape recorder will be controlled automatically so that the dumped CSM PCM data bit rate will always be 51.2 kbps. The record speed of the tape recorder will be controlled by the crew according to the PCM bit rate of the CSM telemetry to be recorded. The capacity of the tape recorder will be one-half hour of recording at the tape speed required for recording 51.2 kbps of CSM PCM telemetry (15 ips) and two hours of recording at the tape speed required for recording 1.6 kbps of CSM PCM telemetry (3.75 ips).

The tape recorder must be rewound before the recorder contents can be dumped. Consequently, recorded information will be dumped in the same direction as it was recorded and in the same order. Recorded information will not be erased during playback. Controls will be provided to enable the crew to run the tape transport in reverse (rewind) at 120 ips and to run the tape transport forward (fast forward) at 120 ips without recording or erasing information. All modes of operation of the tape recorder will be selectable by a crewman from the communications control panel or by the MSFN via the up-data system of the CSM.

The tape recorder will be equipped with a tape-in-motion sensor whose output will be displayed to the crew. An end-of-tape sensing circuit will be included in the tape recorder which will automatically remove power from the associated electronic circuits and the tape drive mechanism when the end of the tape is reached.

Routing of the voice information and data to the DSE will be remotely controlled by a crew member from the communications control panel.

2.2.2.4 Up-Data

The up-data information and commands will be transmitted by the MSFN to the CSM on a 70 kHz subcarrier on the S-band carrier. The PMP will demodulate the 70 kHz subcarrier which has been frequency modulated ($\pm$7.5 kHz peak frequency deviation) by a composite signal including a 2 kHz phase shift keyed digital up-data signal linearly summed with a 1 kHz synchronization reference signal and will route the composite signal to the digital up-data link sub-bit detector and decoder. The sub-bit detector will convert the phase shift keyed signal into a serial digital signal at a rate of approximately 1000 sub-bits per second. The series of sub-bits of one message (up to 150 sub-bits or 30 information bits) will be routed to the decoder where it will be stored and the up-data message checked for its validity. The decoder will provide a coded verification signal to the telemetry system of the CSM for transmission to the MSFN (included in both the high and low bit rate PCM formats, 1.6 and 51.2 kbps, respectively) via the USB system only if a valid up-data message is received. If the up-data message received is not a valid message, the message will be rejected. The decoder will decode and process the message, will determine the proper destination of the up-data message, and will route the appropriate signal to the proper CSM system.

Four types of up-data messages will be possible:

(a) Real-time commands (a total of 64 real-time commands possible) which operate latching relays

(b) Timing pulse trains for reset of the central timing equipment

(c) Data for insertion into the CM guidance computer

(d) Test messages

The crewman will be provided with the capability for releasing latching relays operated via the up-data system and for inhibiting data from entering the guidance computer.

In case of failure of the 30 kHz discriminator in the PMP used to extract voice information from the 30 kHz subcarrier on the S-band carrier transmitted by the MSFN, voice information can be frequency modulated on the 70 kHz up-data subcarrier in a contingency mode by the MSFN. A switch will be provided to enable the crew to route the output of the 70 kHz discriminator to the audio centers as well as to the sub-bit detector and decoder.

2.2.2.5 Television

A portable television camera, which may be transferred to the SWS during the manned SWS phases of the AAP missions but will be routed to Earth with the CM, will provide an output video signal to the PMP for processing prior to transmission to the MSFN via the S-band FM transmitter. When connected to a 92 ohm load, the video output from the camera will extend from -0.75 volts (sync reference level) to +2.75 volts (white reference level).

The portable television camera to be used for this application will be a refurbished color television camera and black and white monitor from the Apollo Program of the type used during the Apollo 10 mission. A slight modification will be made to this type of camera to isolate the power ground from the video signal ground to permit the camera to use SWS power while the output signal is transmitted via the CSM S-band FM transmitter without introducing a ground loop. The video output of this type of camera will meet the standards for black and white television signals contained in the EIA Standard RS170. The frame rate will be 30 frames per second with each frame composed of two interlaced fields (60 fields per second vertical scan rate) and the horizontal scan rate will be 525 lines per frame. The bandwidth of the video signal output of this type of camera will be of the order of 4 MHz, but the S-band transmission system of the CSM will bandwidth limit this signal to approximately 2 MHz. Color will be obtained by using a different colored filter (total of three) in front of the camera tube during each field for three successive fields followed by appropriate processing on Earth after reception of any three successive fields.

The monitor provided with the television camera can operate attached to or separated from the camera. The monitor will be a high impedance device and the input leads to this monitor will be bridged across the output leads of the television camera. The monitor will have a small black and white screen measuring 2x2.75 inches and will have four operating controls (brightness, contrast, horizontal, and vertical).

Preinstalled wiring (coaxial cable) will be provided between the CSM/MDA interface to the television input of the PMP for routing video signals generated in the SWS to the PMP for subsequent transmission to the MSFN via the CSM S-band FM transmitter. A coax switch will be provided in the CM which will disconnect this preinstalled wiring from the television input of the PMP. This will allow the portable color television camera to be used in the CM and be connected directly to the television input of the PMP.

An isolation amplifier will be included in the PMP which will enable the video signal input to the PMP to be routed to ground checkout equipment via a coaxial umbilical cable during prelaunch checkout activities.

2.2.2.6 Tracking

The USB PM transponder will enable stations of the MSFN to track the CSM (relative velocity and position determination). The PM transponder will transmit a carrier which will be phase-coherent with the S-band carrier received by the CSM USB transponder (for determination of relative velocity) and will turn-around the pseudo-noise range code received by the CSM USB transponder for transmission by the CSM USB system (for determination of relative range).

The VHF ranging system of the CSM will enable the range between the CSM and a remotely located VHF ranging transponder to be established. The VHF ranging system of the CSM will consist of a digital range generator (DRG) and the 259.7 MHz amplitude modulation transmitter and the 296.8 MHz amplitude modulation receiver discussed earlier. Three square wave range tones (coarse tone: 247 Hz; mid tone: 3.95 kHz; fine tone: 31.6 kHz) will be generated by the DRG. The combination of tones to be transmitted via the 259.7 MHz transmitter will be selected automatically by the DRG according to a particular sequence most suitable for acquisition and lockup of the ranging system. The following three combinations will be used: (a) coarse tone added (modulo-2) to the mid tone, (b) mid tone alone, and (c) fine tone alone. The DRG will compare the phase between its transmitted tone(s) and the tone(s) received by the 296.8 MHz receiver which will be the transmitted tone(s) turned around by a remotely located VHF ranging transponder. The range between the CSM and the VHF ranging transponder will be derived from the difference in phase between the transmitted and received tone(s). This range readout will be routed to the CM computer and to a display for the crew.

2.2.3 Personal Communications Systems of the Crewmen

Each crewman will be capable of operations clad in a spacesuit (the Apollo A7LB spacesuit) or in shirtsleeve attire. The crewmen will be capable of performing either intravehicular activities (IVA) or extravehicular activities (EVA) when clad in the spacesuit. The spacesuit will be provided with an umbilical supported life support system (Astronaut Life Support Assembly - ALSA) including a pressure control unit (PCU) chest pack similar to the one used in the Gemini Program.

Regardless of the location of the crewmen, biomedical data transfer capability from each crewman to the MSFN and voice communications capability between each crewman and the other crewman will be provided. Each crewman will be equipped with a personal communications system (PCS) which provides the capability for biomedical data transfer and voice communications.

2.2.3.1 Voice Communications

Each crewman will be provided with two headsets, a communications carrier and a light weight headset. The communications carrier consists of a communications soft hat, which will include independently operating earphones and redundant microphones with self-contained preamplifiers. The light weight headset consists of a light weight head clamp, a single earphone and a single microphone with a self-contained preamplifier. The communications carrier must be used when a crewman is wearing his spacesuit and can be used when a crewman is in shirtsleeve attire. The light weight headset can only be used when the crewman is in shirtsleeve attire. When used with the spacesuit, the communications carrier will be plugged into a wiring harness which will be an integral part of the spacesuit which will interface with the EVA/IVA umbilical cable. A T-adapter cable will be used to provide the interface between the communications carrier when used without the spacesuit or the light weight headset and the crewman communications umbilical (CCU). The EVA/IVA cable and the CCU will provide the interface between the PCS of each crewman and the voice communications and telemetry systems of the spacecraft.

The EVA/IVA umbilicals will be different from the CCU's. The functions of commodity (water coolant and oxygen) supply and transfer of data from the spacesuit on commodities supplied will be provided through the EVA/IVA cable but not through the CCU. The caution and/or warning tones from the spacecraft CWS will not be allowed to reach a crewman through the EVA/IVA umbilical when a crewman is performing EVA but will be allowed to reach a crewman through the CCU or through the EVA/IVA cable when performing IVA.

Each crewman will be provided with two different CCU's, one for use with an audio center in the CM and the second for use with a speaker/intercom unit in the SWS. The CCU's provided for use in the SWS will include a volume control potentiometer and a rocker switch conveniently located for operation by a crewman. The volume control potentiometer will be wired into the headset lines of the CCU to enable a crewman to control the level of the voice signals reaching his headset. The alarm tones from the AM CWS reaching the headset of a crewman through this CCU will bypass this potentiometer and be unaffected by its setting. The rocker switch in conjunction with suitable wiring (one of the two voice communications hardlines) in the SWS and CM will enable a crewman to key the intercom bus of an audio center in the CM or to key both the intercom bus and the RF transmitters previously selected on that audio center to which the voice communications hardline is connected.

Although the CCU's to be used in the CM do not include either a volume control potentiometer or a rocker switch, a control head will be provided for use in conjunction with each of these CCU's. Each control head will include a rocker switch to enable a crewman to key the intercom bus alone or to key both the intercom bus and the RF transmitters previously selected on the audio center where the CCU is connected when that audio center is operating in the proper mode.

A similar switch will be conveniently located on the chest pack of the spacesuit for use by a crewman performing EVA or IVA. This switch will provide the crewman with the same capibilities as the rocker switches discussed above.

The EVA/IVA cables and both types of CCU's will include the necessary wiring to permit: (a) powering of the microphones and preamplifiers of the headsets, (b) transferring voice and/or alarm signals to and from the headsets, (c) operating the PTX circuitry of an audio center, (d) powering of the biomedical instrumentation and telemetry system, and (e) transferring crewman biomedical data.

2.2.3.2 Instrumentation and Telemetry

Each crewman will normally wear a biomedical harness equipped with biomedical sensors, transducers, and signal conditioners and preamplifiers to provide the necessary operational biomedical data on the crewman including electrocardiogram

(ECG), heart rate (processed from the ECG signal by a signal conditioner in the harness), impedance pneumograph (ZPN), and body temperature measurements. Identification of the biomedical data with respect to a crewman will be accomplished through different DC voltage levels in the subject identification channel from each harness.

The EVA/IVA cables and both types of CCU's in conjunction with the T-adapter discussed above will include the necessary wiring to permit powering of the biomedical instrumentation and telemetry system by the spacecraft electrical power system. The EVA/IVA cables and the SWS CCU will include the necessary wiring to permit the transfer of the four biomedical data signals listed above plus the crewman identification signal from the harness to the telemetry system of the spacecraft. The CSM CCU will only include the wiring necessary to permit the transfer of the ECG and ZPN signals from the biomedical harness to the telemetry system of the spacecraft.

When a crewman is clad in a spacesuit during EVA/IVA operations, data on spacesuit environment will be gathered by sensors, transducers and signal conditioners located in the PCU and in the suit water coolant loop. The suit environment measurements which will be routed through the EVA/IVA umbilicals will include suit gas pressure, suit gas inlet temperature and suit water outlet temperature.

2.3 Mission SL-1/SL-2

The communications systems of the various modules in mission SL-1/SL-2 are described in the sections as designated below:

(a) CSM in Section 2.2.2,

(b) Crewmen in Section 2.2.3, and

(c) SWS in Section 2.1.2

The interfaces between the communications systems of the various modules in mission Sl-1/SL-2 are described below.

The radio frequency systems of the various modules in mission SL-1/SL-2 are listed in Table 2.3.1

2.3.1 Voice Communications

Voice communications capability among the crewmen during mission SL-1/SL-2 regardless of the location of each crewman (in the CM, MDA, AM, OWS or performing IVA or EVA) will be provided via hardline connections. The redundant voice communications hardlines branched into the MDA, AM, and OWS will be provided with umbilical disconnects at various locations convenient to work and sleep stations in the SWS (Section 2.1.2.2.1). These umbilical disconnects will be compatible with the electrical umbilicals of the PCS of each crewman. The amplifier/isolation unit included in each of the two voice communications hardlines will provide the communications signal interface between each hardline and a different audio center of the CM. Different quick disconnect connectors at the interface between the CSM and the axial port of the MDA will be used to provide the hardline connections of cables between each amplifier/isolation unit in the SWS and a different audio center in the CM. These connectors will be 61 pin connectors and will be used to provide all hardline communications and signal interfaces between the CSM and the SWS with the exception of the interfaces between power supply and television systems of the CSM and AM. Mating of these connectors will be accomplished by a crewman within the docking tunnel of the CM. A feed-through arrangement will be provided in the CM to bypass the CM docking tunnel hatch with the two 61 wire cables when entering the CM pressure vessel to allow the two 61 pin connectors to remain mated with corresponding connectors in the MDA when the CM docking hatch is closed. Those wires in each of the 61 wire

TABLE 2.3.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-1/SL-2

Location	System	Frequency (MHz) Transmit	Receive	Modulation
CSM	USB Transponder	2287.5	2106.4	PM
	S-Band Transmitter	2272.5		FM
	Recovery Beacon	243.0		ICW
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM
SWS	Telemetry, Recorded Voice	230.4		PCM/FM, FM
	Telemetry, Recorded Voice	246.3		PCM/FM, FM
	Telemetry, Recorded Voice	235.0		PCM/FM, FM
	Up-Data		450	PSK/FM
	VHF Ranging	296.8	259.7	AM
	Experiment M509/T020 Telemetry*	26.0	26.0	FSK
ATM	Telemetry	231.9		PCM/FM
	Telemetry	237.0		PCM/FM
	Up-Data		450	PSK/FM

*Internal to the OWS

cables related to voice communications will be branched from the main cables and will be routed to a different audio center in the CM, the LMP audio center and the CDR audio center, respectively. Parallel wiring to these two audio centers will enable a crewman via an appropriate switch on each of the two audio centers, to configure each audio center for use by either a voice communications hardline of the SWS or the PCS of a crewman.

Since the voice communications hardline connection to an audio center of the CM will be indistinguishable to the audio center from a crewman's PCS connection, all of the voice signal routing options available in the audio centers under normal CSM alone operations (Section 2.2.2.2) will also be available for combined CSM and SWS operations. Bridging of the two voice communications hardlines to form a single conference circuit will be possible by using the intercom bus switch settings on the appropriate audio centers. Also through appropriate switch settings on the various audio centers, either or both of the voice communications hardlines may be connected to the VHF and/or USB communications systems of the CSM to provide a voice communications link between the OA and a station of the MSFN. Since sidetone will be provided in all transmit modes by each audio center, it will be possible through proper switch settings on the appropriate audio centers to make each of the voice communications hardlines an independent conference circuit. It should be noted that a crewman in the CM whose PCS would be connected to the third audio center of the CM can be connected to either, both, or neither of voice communications hardlines as determined by his selection of switch settings on this third audio center.

Selection by a crew member of the specific RF system (VHF and/or USB) of the CSM and the specific voice communications hardline used to provide voice communications between the OA and a station of the MSFN will only be possible from within the CM. Crew members located in the CM, MDA, AM, or OWS will be able to key the previously selected RF transmitter in the CSM by operating a PTX switch on the speaker/intercom unit (in the MDA, AM or OWS), CM speaker box, or the CCU of the PCS from any remote location.

Controls will be provided on each speaker/intercom unit in the SWS to enable a crewman in the SWS to activate a tape recorder in the tape recorder-reproducer subsystem of the AM if none is operating and route audio signals present on that one of the voice communications hardlines previously selected manually by a crewman in the AM to the tape recorder-reproducer subsystem of the AM, or to inhibit recording of all voice communications by the tape recorder-reproducer subsystem of the AM. A visual display will be provided on each speaker/intercom unit in the SWS to indicate when voice communications are being recorded by the tape recorder-reproducer subsystem of the AM. A crewman located in the CM will not be provided with the capability to control the tape recorder-reproducer subsystem of the AM for voice communications storage nor be provided with a display to indicate that voice communications signals are being recorded in the AM. Voice signals from a crewman in the CM can be recorded by the tape recorder-reproducer subsystem of the AM only if the proper switches have been operated in the SWS. A crewman in the CM will have the capability to activate the DSE of the CSM to record voice signals generated by him exclusively or the voice communications on either of the two voice communications hardlines.

A momentary switch control will be included on the intercom box in the CM and on each of the speaker/intercom units in the SWS to provide a crewman with a call capability. If the call is initiated in the CM, the headset lines of the two voice communications hardlines will be connected in the SWS. If the call is initiated in the SWS, the microphone lines of the two voice communications hardlines will be connected in the SWS. If any call control is operated, the sleep mode of operation of the various speaker/intercom units in the SWS, the CM intercom box, and the PCS's of the crewmen in the SWS will be overridden, the warning alarm of the SWS CWS will be activated, and the calling station will be configured to allow a crewman to transmit voice signals over the voice communications hardlines. Operation of this call control in the CM will provide a relay contact closure to the SWS. Operation of one of these controls in the SWS will provide a relay contact closure to the CSM.

2.3.2 Telemetry

Biomedical data from up to two crewmen located anywhere in the MDA, AM, or OWS, or performing EVA will be routed via a hardline connection from the PCS of each crewman to the instrumentation and telemetry system of the AM for processing and transmission to the MSFN as described in Section 2.1.2.3. Biomedical data from up to three crewmen located in the CM will be routed via a hardline connection from the PCS of each crewman to the instrumentation and telemetry system of the CSM as described in Section 2.2.2.3.

There will be no interface between the instrumentation and telemetry systems of the AM and the CSM.

2.3.3 Up-Data

It will be possible for the MSFN via the up-data system of the AM to select the particular one of the four antenna elements of the S-band antenna subsystem of the CSM to be connected to the S-band triplexer of the CSM USB communications system. Switching of the S-band antenna elements will be accomplished by commands to the AM up-data system which will operate the proper two of three relays in the Am. Contact closures on the two relays in the AM will complete a circuit thereby operating the appropriate relay(s) in the CSM which will connect the triplexer to the proper S-band antenna element.

Four relays will be provided in the CSM to implement this interface, one corresponding to each S-band antenna element. Contacts of one relay will be normally closed and the S-band triplexer will be connected to the antenna element corresponding to this element unless a command to switch to another antenna element is received by the AM up-data system or by the CSM up-data system or unless a crewman operates the appropriate switch on the communications control panel in the CM. Receipt of such a command will result in opening the contacts of this relay and closing the contacts of one of the other three relays.

The hardline interface between the MDA and the CM will consist of four wires, one wire carrying 28 volt DC power and three return wires, which will be appearing in one of the two 61 pin connectors which form the communications and signal hardline interface between the MDA and the CM.

2.3.4 Television

The OA will be provided with the capability to transmit, in real-time only, video signals generated by either a portable television camera, described in Section 2.2.2.5 or by any one of the cameras of the television system of the ATM described in Section 2.1.3.4. The video signals from either of these two sources, but not both simultaneously, will be transmitted from the OA via the S-band FM transmitter of the USB system of the CMS described in Section 2.2.2.1.1. Pre-installed wiring and switches will be provided in the SWS as described in Section 2.1.2.5 and in the CM as described in Section 2.2.2.5 for the transfer of the video signals from the portable camera or from the ATM television system to the PMP of the CSM for subsequent transmission via the S-band FM transmitter.

Coaxial cable connector will be provided at the CSM/MDA interface to provide the connection between the coaxial cables of the SWS and the CSM. No conditioning of the video output signal from the portable television camera will be provided in the SWS or CM before the signal reaches the PMP of the CSM. The video output signal from the camera of the ATM television system chosen for transmission to the MSFN will be conditioned in the SWS before it is routed to the CSM to look like the video output signal from the portable television camera.

2.3.5 Tracking

The VHF ranging system of the CSM (Section 2.2.2.6) in conjunction with the VHF ranging transponder of the SWS (Section 2.1.2.6) will enable the CSM to determine the range between the CSM and the SWS for display to the crew during the CSM rendezvous with the SWS.

2.4 Mission SL-3

The communications systems of the various modules in mission SL-3 are described in the sections as designated below:

(a) Saturn IB Launch Vehicle in Section 2.2.1,

(b) CSM in Section 2.2.2, and

(c) Crewmen in Section 2.2.3

The radio frequency systems of the various modules in mission SL-3 are listed in Table 2.4.1.

For missions SL-3 and SL-1/SL-3, experiments S071 (Circadian Rhythm-Pocket Mice) and S072 (Circadian Rhythm-Vinegar Gnat) will be installed in the SM. The hardware for experiments S071/072 will include a data system with provisions for collecting, processing, and storing data pertinent to these two experiments. This data system will collect analog and digital data from the two experiments, will digitally encode the data, and will store the data with a time reference in a core memory. The core memory will have a capability sufficient to store data from these experiments for a period of 19 hours which corresponds to a storage capacity of the order of 38,000 bits. The planned duration of these experiments is 30 continuous days. Since no provisions will be included in the CM to store data dumped from the core memory of the data system of experiments S071/072 for eventual return to the Earth with the CM, the PCM telemetry system (Section 2.2.2.3) and the USB system (Section 2.2.2.1.1) of the CSM will be used to transfer the data dumped from the core memory to the MSFN at least once every 19 hours.

Control of experiments S071/072 will be accomplished by the MSFN via the up-data system of the CSM or manually in contingency situations by a crewman from a control panel located in the CM. Three set/reset commands will be provided; namely, (a) initiate, (b) dump stored data, and (c) transmit data collected in real-time.

One complete cycle of the data collection format will occur every 40 minutes and will be composed of 4 subframes covering 10 minutes each. Each subframe will consist of 42 words of 8 bits each or 336 bits. Each of the four subframes will be uniquely identified by the last two bits of the time code word in that subframe. This data may be routed to core memory for storage or by routed to the PCM telemetry subsystem in real-time as generated. Upon command, the data stored in

TABLE 2.4.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-3

Location	System	Frequency (MHz) Transmit	Receive	Modulation
S-IB	Telemetry	240.2		FM/FM
	Telemetry	256.2		PCM/FM
	Command-Destruct		450	FSK/FM
S-IVB	Telemetry	258.5		PCM/FM
	Command-Destruct		450	FSK/FM
IU	Telemetry	250.7		FM/FM
	Telemetry	245.3		PCM/FM
	Up-Data		450	PSK/FM
	C-Band Transponder	5765.0	5690.0	Pulse
CSM	USB Transponder	2287.5	2106.4	PM
	S-Band Transmitter	2272.5		FM
	Recovery Beacon	243.0		ICW
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM

the core memory will be read out destructively and be transferred to a buffer in a bit-serial mode. Similarly upon command, the data generated in real-time will also be transferred to the buffer. The digital data will be routed from the buffer of the data system of experiments S071/072 to the PCM telemetry subsystem of the CSM in blocks of 24 bits in digital parallel form on 24 separate wires (with 3 data return wires). The 24 data wires plus one data return wire for each block of 8 data wires will be routed to three 8-bit digital parallel input channels to the CSM PCM telemetry system which will be sampled successively by the sampling program format and will appear in adjacent time slots of the output PCM bit stream. In order that the core memory loaded to its full capacity can be dumped during an average pass over a single MSFN station, the digital parallel channels of the sampling format of the PCM telemetry system which are sampled 10 times per second will be assigned to support experiments S071/072. Hence, each group of 24 bits of parallel digital data will be presented by the buffer to the PCM telemetry system for sampling for a duration somewhat greater than 100 milliseconds. At this dump rate, dump of the core memory will have been completed within 170 seconds. It should be noted that only the high bit rate sampling program (resulting in an output PCM bit stream of 51.2 kbps) will have sufficient digital parallel channel capacity to support the data retrieval requirements of experiments S071/072.

2.5 Mission SL-1/SL-3

The communications systems of the various modules in mission SL-1/SL-3 are described in the sections as designated below:

(a) CSM in Section 2.4,

(b) Crewmen in Section 2.2.3, and

(c) SWS in Section 2.1.2.

The interfaces between the communications systems of the various modules in mission SL-1/SL-3 are the same as described in Section 2.3 for mission SL-1/SL-2.

The radio frequency systems of the various modules in mission SL-1/SL-3 are listed in Table 2.5.1.

TABLE 2.5.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-1/SL-3

Location	System	Frequency (MHz) Transmit	Frequency (MHz) Receive	Modulation
CSM	USB Transponder	2287.5	2106.4	PM
	S-Band Transmitter	2272.5		FM
	Recovery Beacon	243.0		ICW
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM
SWS	Telemetry, Recorded Voice	230.4		PCM/FM, FM
	Telemetry, Recorded Voice	235.0		PCM/FM, FM
	Telemetry, Recorded Voice	246.3		PCM/FM, FM
	Up-Data		450	PSK/FM
	VHF Ranging	296.8	259.7	AM
	Experiment M509/T020 Telemetry*	26.0	26.0	FSK
ATM	Telemetry	231.9		PCM/FM
	Telemetry	237.0		PCM/FM
	Up-Data		450	PSK/FM

*Internal to the OWS

2.6 Mission SL-4

The communications systems of the various modules in mission SL-4 are described in the sections as designated below:

(a) Saturn IB Launch Vehicle in Section 2.2.1,

(b) CSM in Section 2.2.2, and

(c) Crewmen in Section 2.2.3.

The radio frequency systems of the various modules in mission SL-4 are listed in Table 2.6.1.

Experiment S061 (Potato Respiration) will be carried by the CM during missions SL-4 and SL-1/SL-4. A self-contained data system in experiment S061 will collect data pertinent to the experiment, will process the collected data, and will store the data in storage registers. Only two parameters will be monitored -- a differential pressure and a temperature. The output analog signal from the differential pressure transducer will be sampled at a rate of one sample per minute and the sample voltage value will be converted into binary form with an 8-bit accuracy. The analog output signal from the temperature sensor will also be sampled once per minute and the sample voltage value will be converted into binary form with a 5-bit accuracy. The 5-bit and 8-bit digital words will be routed to storage registers for storage. The storage registers will provide sufficient capacity to store a minimum of 250 digitized samples of each parameter. Consequently, the storage registers must be dumped at least once every 250 minutes in order to avoid loss of any experiment data.

The same method used to transfer stored data from experiments S071/072 to the MSFN during mission SL-3 (Section 2.4) will be used to transfer the data collected by the data system of experiment S061 during mission SL-4. The interface between the CSM PCM telemetry system and experiment S061 will consist of 24 wires for the transfer of digital parallel data and three data return wires -- one return wire for each group of eight data wires. Upon command, the data stored in the storage registers will be transferred into a buffer in parallel word form -- 8-bit words for differential pressure transducer data and 5-bit words for temperature sensor data. The 24 data wires will be routed to three 8-bit digital parallel input channels to the CSM PCM telemetry system which will be sampled successively by the high bit rate sampling program at a rate of 10 samples per second and will appear in adjacent time slots in the output 51.2 kbps NRZ-L PCM bit stream. Each group of three words of parallel digital data will be presented by the

TABLE 2.6.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-4

Location	System	Frequency (MHz) Transmit	Frequency (MHz) Receive	Modulation
S-IB	Telemetry	240.2		FM/FM
	Telemetry	256.2		PCM/FM
	Command-Destruct		450	FSK/FM
S-IVB	Telemetry	258.5		PCM/FM
	Command-Destruct		450	FSK/FM
IU	Telemetry	250.7		FM/FM
	Telemetry	245.3		PCM/FM
	Up-Data		450	PSK/FM
	C-Band Transponder	5765.0	5690.0	Pulse
CSM	USB Transponder	2287.5	2106.4	PM
	S-Band Transmitter	2272.5		FM
	Recovery Beacon	243.0		ICW
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM

buffer to the CSM PCM telemetry system for sampling for a duration somewhat greater than 100 milliseconds. All data from the differential pressure transducer storage register will be dumped before the data from the temperature sensor storage register is dumped. During the dumping of data, all stored data will be repeated two times before the shift registers will be erased. Under these conditions, the data dump from experiment S061 will be completed in approximately 40 seconds. It should be noted that it is planned to operate this experiment continuously throughout missions SL-4 and SL-1/SL-4.

2.7 Mission SL-1/SL-4

The communications systems of the various modules in mission SL-1/SL-4 are described in the sections as designated below:

(a) CSM in Section 2.6,

(b) Crewmen in Section 2.2.3, and

(c) SWS in Section 2.1.2.

The interfaces between the communications systems of the various modules in mission SL-1/SL-4 are the same as described in Section 2.3 for mission SL-1/SL-2.

The radio frequency systems of the various modules in mission SL-1/SL-4 are listed in Table 2.7.1.

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TABLE 2.7.1

RADIO FREQUENCY SYSTEMS TO BE CARRIED BY THE SPACE VEHICLE IN MISSION SL-1/SL-4

Location	System	Frequency (MHz) Transmit	Frequency (MHz) Receive	Modulation
CSM	USB Transponder	2287.5	2106.4	PM
	S-Band Transmitter	2272.5		FM
	Recovery Beacon	243.0		ICW
	Voice, VHF Ranging	259.7		AM
	Voice		259.7	AM
	Voice	296.8		AM
	Voice, VHF Ranging		296.8	AM
SWS	Telemetry, Recorded Voice	230.4		PCM/FM, FM
	Telemetry, Recorded Voice	235.0		PCM/FM, FM
	Telemetry, Recorded Voice	246.3		PCM/FM, FM
	Up-Data		450	PSK/FM
	VHF Ranging	296.8	259.7	AM
	Experiments M509/T020 Telemetry*	26.0	26.0	FSK
ATM	Telemetry	231.9		PCM/FM
	Telemetry	237.0		PCM/FM
	Up-Data		450	PSK/FM

*Internal to the OWS

ACRONYMS AND ABBREVIATIONS

AFETR - Air Force Eastern Test Range

ALSS - Astronaut Life Support System

AM - Airlock Module

AM - Amplitude Modulation

ASA - Amplifier and Switch Assembly

ASAP - Auxiliary Storage and Playback Assembly

ATM - Apollo Telescope Mount

AVC - Automatic Volume Control

AVP - Address Verification Pulse

BCD - Binary Coded Decimal

bps - bits per second

CCS - Command and Communications System

CCU - Crewman Communications Umbilical

CMG - Control Moment Gyro

CRDU - Command Relay Driver Unit

CRP - Computer Reset Pulse

CSM - Command and Service Module

CTE - Central Timing Equipment

CWS - Caution and Warning System

dB - Decibel

dBm - Decibel with respect to a 1 milliwatt reference

DC - Direct Current

DDAS - Digital Data Acquisition System

Acronyms and Abbreviations

DRG - Digital Range Generator

DSE - Data Storage Equipment

ECG - Electrocardiogram

EIA - Electronic Industries Association

EVA - Extravehicular Activity

FM - Frequency Modulation

FSK - Frequency Shift Keyed Modulation

GSE - Ground Support Equipment

HF - High Frequency: 3-30 MHz

H/L - High Level

IB - PCM Interface Box

IC - Intercom

IEU - Interface Electronics Unit

IF - Intermediate Frequency

ips - inches per second

IRIG - Inter-Range Instrumentation Group

IU - Instrument Unit

IVA - Intravehicular Activity

kbps - kilobits per second

kHz -

LES - Launch Escape System

L/L - Low Level

LVDA - Launch Vehicle Data Adapter

LVDC - Launch Vehicle Digital Computer

Acronyms and Abbreviations

MCC - Mission Control Center

MDA - Multiple Docking Adapter

MHz -

msec - millisecond

MSFN - Manned Space Flight Network

mVDC - millivolts DC

NRZ-L - non-return-to-zero level: "one" is represented by one level and "zero" is represented by the other level

NRZ-S - non-return-to-zero space: "one" is represented by no change in level and "zero" is represented by a change in level

OA - Orbital Assembly: SWS, ATM, and any docked module

OWS - Orbital Workshop

PAM - Pulse Amplitude Modulation

PCM - Pulse Code Modulation

PCS - Personal Communications System

PCU - Pressure Control Unit

PM - Phase Modulation

PMP - Premodulation Processor

PN - Pseudo Noise

pps - pulses per second

PRF - Pulse Repetition Frequency

PS - Payload Shroud

PSK - Phase Shift Keyed Modulation

PTT - Push-to-Talk

PTX - Push-to-Transmit

Acronyms and Abbreviations

RACS - Remote Automatic Calibration System

RASM - Remote Analog Submultiplexer

RDM - Remote Digital Multiplexer

RF - Radio Frequency

RTC - Real-Time Command

RTTA - Range Tone Transfer Assembly

RZ - Return-to-zero: "one" is represented by a half-bit wide pulse and "zero" is represented by no pulse condition

SCE - Signal Conditioning Equipment

SCR - Signal Conditioning Rack

SLA - Apollo Spacecraft Lunar Module Adapter

SPC - Stored Program Command

STS - Structural Transition Section

SWS - Saturn Workshop: OWS/AM/MDA/IU/PS

T_r - Time-to-go-to-retro

T_x - Time-to-go-to-equipment-reset

TACS - Thruster Attitude Control Subsystem

TWT - Traveling Wave Tube

UHF - Ultra High Frequency: 300-3000 MHz

USB - Unified S-Band

VCO - Voltage Controlled Oscillator

VDC - Volts DC

VHF - Very High Frequency: 30-300 MHz

Acronyms and Abbreviations

VOX - Voice Operated Transmission Switch

X-IOP - X-axis of the SWS in the orbital plane

Z-LV - Z-axis of the SWS coincident with the local vertical

ZPN - Impedance Pneumograph